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EDITORIALS

SYMPOSIUM - WAR CASUALTIES

This issue of the JOURNAL is being devoted entirely to papers delivered at the 1942 meeting of the Hawaii Territorial Medical Association—a Symposium on the Disposition of War Casualties. The usual feature columns are omitted from this number; they will appear again as usual in the November-December issue.

This symposium was planned as a collective review of experiences in war surgery as practised by those who were active in the Navy and Army hospitals of Oahu on December 7 and subsequently. From this vantage point of several months we hoped to look back critically on our early work and to crystallize our ideas. We hoped that the new arrivals in the armed medical services, whose war experience did not extend back to the attack on December 7, would profit by these reports.

The authors and their discussants were carefully chosen from among those present and active on December 7 so that only first-hand experiences would be reported. The Program Committee is greatly indebted to the Army and Navy medical services for their ready cooperation in making this program possible, and to Lt. Comdr. A. T. Walker for ably conducting and coordinating the panel discussion. Proof of the interest in the program was the record attendance of some 325 physicians, members of the Association and of the Medical Corps of the Army and Navy, the latter easily identified by uniforms, gas masks, "tin hats," and in some instances, sidearms.

The papers and statements appearing in this issue of the HAWAII MEDICAL JOURNAL are those of the authors, in their unofficial capacity as physicians and surgeons, and are not to be construed as official or as reflecting the views of the Navy Department or the War Department or any branch or subdivision thereof.

FIRST ANNIVERSARY

It is just a year since the Bulletin of the Hawaii Territorial Medical Association became the HAWAII MEDICAL JOURNAL. It is a good time to take stock of how nearly we have come to justifying our existence, and of how we may in the future improve over past performances.

A medical journal published in a relatively remote locality like Hawaii must serve two primary purposes: first, that of uniting the physicians of that locality through a single means of expression, by which they may be informed or may themselves inform others; and second, that of providing a convenient record of medical facts *pertinent to the locality concerned.*

This last phrase will bear serious consideration. If a provincial medical journal accepts and publishes articles of wide, unrestricted scope and application, there is danger that it will usurp the functions of the Journal of the American Medical Association or of the regional medical journals, and that it will find itself on occasion publishing material merely because the material was not good enough to justify its acceptance by a more widely circulated publication. If, on the other hand, a provincial journal accepts for publication articles of extremely limited scope, such as reports of extraordinarily rare diseases or highly technical research problems, it will be in danger of wrongly assuming the proper function

of the many excellent specialistic journals whose task it is to disseminate such information to those physicians who are particularly interested. Again, the result is likely to be the publication of inadequately prepared material.

We are quite aware that we have already sinned to some extent in respect to both of these rules. We are proud, however, of having already been able in several instances to publish good papers on distinctively local problems.

The definition of what constitutes a "distinctively local problem" may vary a little from time to time. At the present time we feel that war medicine and war surgery have some claim to be included in that category, and for this reason we have allowed this first issue of Volume 2 to consist exclusively of papers relative to the disposition of war casualties. All of these were delivered and discussed at the annual meeting of the Hawaii Territorial Medical Association in August.

We are also inclined to recognize the existence of a few minor and occasional exceptions to our general rule. A "local" journal, particularly when it serves such a comparatively small medical population, may very well serve the purpose of providing a relatively immediate outlet for brief preliminary reports of subjects which merit more extensive or more detailed consideration in either a more widely circulated or a more highly specialized publication at a later date. Another exception is found in articles which have outstanding educational value. It has been and will continue to be our effort to publish such articles under the headings of our three regular columns, Progress in Internal Medicine, Recent Advances in Surgery, and Clinicopathologic Comment. Reports of interesting and instructive cases—not merely "rare" cases—would be included in this category. Still another exception, for Hawaii, may lie in the fact that we are at a considerable distance from the Mainland, and that our journal may therefore very well subserve in some degree the task of a regional medical journal. This, however, is a privilege which we will try not to abuse.

With these general principles to guide us, we are looking forward to a second year of existence in which we hope we may go further toward proving that the physicians of the Territory of Hawaii need, and are justified in continuing to maintain, the HAWAII MEDICAL JOURNAL.

NAVY "E" FOR WYETH

Until recently the awarding of the Navy's much coveted industrial "E" Pennant has been limited to ship yards, arms manufacturers and the like. Only fifty firms have so far merited such recognition. A recent addition to this distinguished list is John Wyeth & Brother Company, Inc., the first pharmaceutical house to win the Navy's plaudits for its war efforts.

Rear Admiral Charles M. Oman, M.C., U.S.N., who made the award, said, in commenting on Wyeth's attainment, "It is often difficult to make workers realize how vital to the Navy is their individual effort. But I am sure no such problem is present here. There are no workers in the nation closer to the fighting front—to the bloody actions affecting the future of the entire world. Your contributions, which can be considered only in terms of the alleviation of human suffering, are beyond price. The tablets and extracts which you have been turning out and shipping to the Navy at a phenomenal pace are right out there with the fighting units—with the task forces on the Pacific blasting at Jap bases—in the tiny sick bay of a lone submarine stalking an enemy troop ship—aboard a destroyer plowing the north Atlantic to keep the sealanes open. Wherever our men are fighting, the threat of suffering and disaster is lessened by the presence of the drugs you've sent them.

"On shore, in this plant, you people have distinguished yourselves. You are doing an outstanding job for the Navy and the Navy expresses its thanks by awarding you this pennant. On it is the Navy's traditional anchor signifying your service to the Navy as a whole. Beside it is the large white "E" which proclaims to all who see it that you are leaders in your field."

The whole pharmaceutical trade and the entire medical profession may well applaud the Wyeth winning of the "E". The Navy awards it with great reserve, and with the same veneration accorded its service counterpart—the white "E" painted on a warship's turrets for efficiency in gunnery. And Wyeth won the "E" fair and square. The target was an unbelievable figure in production volume. The sights were right on!

War Wounds

A. W. SPITTLER, LIEUTENANT COLONEL, M.C. U.S.A.*

In speaking of wounds in general in connection with war casualties we are speaking of potentially infected wounds, for all war wounds are contaminated. Although the treatment of these wounds has been almost revolutionized during the past few years by the advent and increasing use of sulfanilamide and its allied products, both locally and generally, the basic principles of surgery in their treatment have not changed materially since the last war.

The treatment of several hundred casualties at Tripler General Hospital on December 7 and on subsequent days did a great deal toward convincing us that the local use of sulfanilamide powder was almost miraculous in producing cleanly healing uninfected wounds.

The fact that Dr. Moorhead was delivering a series of lectures on war wounds to this group at the time had a very beneficial effect on the type of surgery done. The fact that he emphasized thorough debridement and subsequent open treatment for all war wounds went a long way toward making those who were dubious about the open treatment practice it in our operating room when they found him working there also. These two principles, when practiced thoroughly, immediately showed the difference between a poor surgeon and a good one; but there is no doubt that the open treatment keeps the poor surgeon from having too many fatalities due to infection.

Before December 7, and in the subsequent literature of those not acquainted with the experience here, the literature was divided on the relative advisability of the open or closed treatment of wounds after debridement and local implantation of a sulfonamide powder.

There is no doubt that one can "get away" with an occasional case with primary closure if one is a very thorough surgeon and does a meticulous debridement down to the most minute crevice, removing every bit of foreign material and devitalized and soiled tissue, and mechanically washing all surfaces. Another type of surgeon, who does a "careless" inaccurate closure after a fair debridement, at times has a good result because for practical purposes his wound remains open.

* Chief of Surgical Service, Tripler General Hospital.

Prior to December 7, I advocated closing most wounds, and, early in the use of sulfanilamide powder locally in wounds, proudly reported before this society a number of cases which healed promptly on primary closure over the powder. However, these cases were done at a time when our operating room was meticulously clean; we had only a case or two to treat at one time; they were brought to the hospital comparatively early after injury, and we did thorough debridements. The cases which arrived on December 7 soon convinced us that to treat them as we did in ordinary times would take too much time for patient, doctors and facilities. Even with the best of planning and the most adequate facilities, there would still be comparative gross contamination of the operating room and all facilities. The wounds were too extensive and too often multiple to permit painstaking search for all bits of tissue and foreign bodies; so that, as Dr. Moorhead advocated in his subsequent lectures, we had to transform ourselves into war wound surgeons and do the best we could for the most patients. In so doing, parts of wounds were occasionally missed in the cleaning process or recontaminated from the table, and to have closed the skin over these unclean parts, even though sulfanilamide power was present, might have resulted in an infection with at least anaerobic organisms. To leave them open is a safeguard against this trouble and produces no harm. Later closure is easy if they remain uninfected.

In the treatment of war wounds it is assumed that we are taking care of these wounds as a primary treatment, of which previously applied first aid measures are not a part. First aid may have some bearing on our end result, but for purposes of this paper it is sufficient to assume that only gross dirt has been removed and hemorrhage temporarily controlled, with a sterile dressing applied. The use of an antiseptic on the surrounding skin as a first aid measure does no good; it only produces a feeling of false security. The first aid use of a sulfonamide powder as a bacteriostatic agent in the wound should be seriously considered, especially in any cases which might not receive definitive treatment for several hours. The treatment of shock and other preliminary

measures, such as the administration of tetanus toxoid, should be completed before the patients are taken to the operating room for surgical procedures. However, one must remember that shock may recur during the operation and may have to be combatted again and again. (As a practical measure to allow for as much time as can be given to the treatment of shock in our hospital, we have delayed the administration of the tetanus toxoid until the cases reach the ward after operation.)

CLEANSING

After the case is prepared generally for surgery, local preparation of the surrounding skin should include thorough cleansing with soap, water, grease solvents, etc. Shaving should be careful and wide. The application of an antiseptic up to the wound margins is good practice, although not essential if the mechanical cleansing with soap and water is adequate. The use of a large number of drapes is unnecessary.

DEBRIDEMENT

A thorough debridement is then done to include uncovering all tracts and cavities made by the missiles in producing the wound. Too often a perforating or penetrating wound looks so innocent that opening of the skin over it and exploring its depths is not done. These cases often develop infections necessitating later opening and drainage and a prolonged convalescence. When such wounds are opened, there is often much more extensive muscle damage and buried foreign material, such as clothing bits, than was anticipated. If they are thoroughly cleaned out, the layers sprinkled with sulfanilamide powder and the wounds of entrance and exit left open, they can often be completely closed on the third day and the patient returned to duty on the tenth day.

In doing a debridement, a thorough knowledge of anatomy is essential. This, in addition to a good exposure, keeps one from doing any harm. The size of the wound has little effect on its healing, so a good exposure of the depths of each wound should always be obtained, and this can only be accomplished by an adequate skin opening over it. This does not mean extensive slashing of fascial planes and muscle fibers, for should the wound become infected, the operation may have produced more damage than the original injury. Longitudinal openings along normal lines of cleavage do very little damage. Also, it is not necessary to cut away large masses of normal tissue in a debridement: a very thin slice may be sufficient to remove all the devitalized tissue. During the debridement and after, a thorough lavage with saline helps remove foreign material as well as dead tissue, and should be practiced in all cases.

Hemostasis is essential, as a blood clot is an excellent medium for the incubation of organisms. The tying of all large bleeders is an essential part of the debridement of the wound; and in so doing the smallest amount of tissue possible included in the tie comprises one of the things a good surgeon strives for. Tie only the vessel, if possible.

Extensive search for foreign bodies deeply imbedded in bones or far from the wound in inaccessible places, is not indicated. Most of the foreign bodies will be found in the debridement; if not, leave them until later or forever. They may never cause any trouble.

SULFONAMIDE THERAPY

I doubt if anyone who saw the wounds of December 7 remains at all dubious about the efficacy of local implantation of sulfanilamide powder or crystals in the wounds after surgery and even in the operative wounds produced in opening of cavities during the treatment of these patients. We were all convinced that surgery could not claim all the credit. Only a little over one-third of the casualties went to the operating room for extensive surgery in the first three days, the remainder being treated on the various wards, in many instances with inadequate surgery but with sufficient amounts of local sulfanilamide or other sulfonamide powder. An intravenous sulfathiazole preparation which normally is considered corrosive outside of the vein was applied locally on several of the latter cases. This produced just enough corrosive action to cause minor sloughs of devitalized tissue in these wounds and eventually they were as clean as the debrided wounds.

Less than 10 per cent of all the air raid cases treated developed infections, and none was so severe as to cause death or secondary hemorrhage, or to require extensive surgery to control infection, with the exception of the cases treated as gas gangrene suspects. I do not believe that the amount per square inch matters greatly, but the total dosage should be controlled so that an overdose will not be given to a person who has exceptionally good absorption. Thirty grams on an open wound or wounds or in cavities should leave a good margin of safety, though I saw as high as 50 to 60 grams placed in some cases without untoward effects. However, I have seen blood concentrations as high as 15 mgm. per cent following 20 grams placed in

a knee joint. The choice of the drug probably has something to do with the effect. Sulfanilamide powder is the most soluble and in our experience has less tendency to cake than sulfathiazole. We had no experience with sulfadiazine powder but Dr. Perrin Long believes it to be the drug of choice for local as well as general use in war wounds.

The general administration of the sulfonamide drugs must be used in addition to their local use in all extensive wounds, and should be started without delay. Should the patient have an extensive local injury and receive a large local dose of the drug, a blood determination may be taken in eight hours and used as a basis for general administration of more of the drug by intravenous, oral, or subcutaneous routes. The subcutaneous use of 0.8 per cent sulfanilamide solution is very useful where the drug is not tolerated by mouth, and a daily dose of 4 to 6 grams can be given very easily. In the postoperative treatment, the only other drugs needed are sedative and occasionally stimulants. Tonic doses of whole blood or plasma sometimes help in the convalescent period.

SUTURES

Suture material in the wounds produced by trauma should be minimal. The best material for ligation of blood vessels is fine catgut. Silk or cotton might add to foreign body drainage if the wound develops infection. Primo-secondary suture is a fine way to suture these wounds if there is enough skin present to cover the defect. The placing of the suture at the original operation, while the patient is under the anesthetic, obviates the use of another anesthetic for closure of most of these wounds as the sutures can be tied on the third day without an anesthetic if no infection is present in the wound. Should time not permit the placing of these sutures, they can be delayed until time for closure. If infection develops, they cannot be used anyway. For suture material in placing primo-secondary sutures, the heavier silks such as No. 5, No. 8 and No. 18 as well as dermal, No. 20, cotton and silkworm, medium or heavy, are best. Catgut usually becomes too soft to withstand the pull in closure and finer materials break.

There are only two places where the use of primo-secondary suturing or open treatment of wounds should not be used. Scalp wounds, especially those involving skull and brain injury, should be closed. These heal very readily after a thorough debridement anyway, and seldom become infected. Facial injuries should, if possible, have primary closures with thorough cleansing of the underlying tissues before closure, because of the cosmetic result. If they are extensive, however, open treatment may be used.

In extensive wounds the primary suture of vital structures such as nerves and tendons should not be considered except during the first few hours (Moorhead uses six hours as a deadline), and not even then if the wound is grossly macerated and contaminated. All plastic repairs should wait until such time as infection either has been ruled out or has definitely subsided. In the case of nerves and tendons the closure of the wound by suture, secondary suture, plastic closure or skin graft, should be accomplished first.

Blood vessel surgery should be delayed until the tissues have returned to a nearly normal condition about the vessels. At least three to six months is often necessary. The successful treatment of an arterio-venous fistula and an aneurysm of the femoral artery in the group of cases after December 7 plainly showed us the necessity for this delay.

Emphasis may well be laid on these phases of the treatment of war or other traumatic wounds. During the first three days, emergency surgery should be done with increasing reluctance after the first six hours. During the period from the fourth to the seventh day, infections are developing and only the treatment of these should be carried out at this time. During this phase, gas gangrene suspects are for the most part treated. After the eighth day, plastics may be started if no infection has developed. The length of time for individual secondary operations must be carefully gauged in each case, with due regard for the condition of the tissues involved.

In the original dressing of the wound, due consideration should be given to splinting extensive wounds by heavy dressings, plaster and splints. Dressings in general should be inspected after twenty-four hours, then not again for forty-eight hours if the wound is clean and gas gangrene is not suspected. At that time, if primo-secondary sutures have been placed, these are drawn up, provided the wound is clean. After this, dressings are only made on such cases as need further treatment, as in the case of adhesive strapping of areas not adequately closed by the sutures. At these dressings sulfanilamide powder is sprinkled on the raw surfaces: it does no good to waste it on the skin surface.

In infected wounds the best treatment is wet dressings with heat. This may be saline or other solution. The addition of a sulfonamide to the solution may be used or it may be sprinkled on the

wound at the dressing. Of course, in infected phases the drug is given by mouth in the usual dosage of 1 gram every four hours.

GAS GANGRENE

In the treatment of gas gangrene suspects, although this is a separate phase of wound surgery in itself, a thorough secondary debridement is done, with wide incision of fascial planes to expose all layers to the air, and local use of sulfanilamide. Occasionally an amputation may be necessary to save a patient whose limb is grossly contaminated. X-ray treatment was instituted in all our cases and carried on until there were no signs of the disease. Five definite cases were diagnosed out of ten suspects transferred to the gas gangrene ward, and all were so treated. Twelve other cases were given prophylactic x-ray treatment. All of these cases were given sulfanilamide by mouth during this period. They were isolated for about two and a half weeks. All of these cases recovered without therapeutic amputation, although one case developed the disease in a high thigh amputation stump.

PLASTIC REPAIR

Extensive skin loss should always be considered for early grafting, should primary treatment produce a clean wound. With the use of sulfonamide powder this can now often be done within two weeks of the injury. The use of all types of grafts can be made. In my experience, sliding and pedicle grafts produced the best results where there was great loss of subcutaneous tissue. Large split-thickness grafts with the use of the dermatome are good where the loss of tissue is not as great.

ANESTHETICS

An anesthetic agent used extensively in the treatment of war wounds at our hospital was intravenous pentothal sodium. It is a good agent if there are no contraindications to its use. Local anesthesia does not allow for the best debridement, in extensive cases. Spinal anesthesia where it can be used is good. Nitrous oxide and oxygen was also used extensively in our cases, as well as open drip ether.

During the period since December 7, there has been a much higher incidence of the type of injuries requiring open treatment. We have made it a definite rule at Tripler General Hospital to treat them in that manner. Of approximately 80 cases treated, there have been no severe infections. There was one death due to secondary hemorrhage from a fecal fistula which eroded an iliac artery at an area which had been damaged at the time of the original injury. However, most of these cases are treated within the optimum period. In the cases of December 7 which developed gas gangrene, most were treated early on the first day of surgery, but most of them were treated by closed methods.

SUMMARY

Two principles of surgery, thorough debridement and subsequent open treatment, are essential to produce uniform good results in the treatment of wounds produced in war casualties.

The local use of a sulfonamide powder, combined with the general administration by oral, intravenous or subcutaneous routes, does a great deal to reduce the incidence of infection in these wounds.

Wounds should be watched carefully early in their treatment for infection and gas gangrene. Gas gangrene can be combatted successfully by surgery, sulfanilamide locally and generally, and x-ray therapy. Wet dressings are best for infections.

DISCUSSION

COMMANDER T. W. DOWNES, M. C., U. S. N. R.: This paper of Col. Spittler's is an excellent one, on which it is a privilege to comment. It gives, I think, a summary of the best opinion at the present time in regard to the treatment of war wounds.

In common with much of the recent literature, Col. Spittler, it seems to me, rather underestimates the bactericidal effect of the patient's own tissues, and lays too much stress upon chemotherapy. He describes, it is true, the thorough mechanical cleansing and debridement, careful hemostasis, and other things that should be done, but my general impression upon first reading this paper was that if only the "magic medicine" is used in large enough quantities, nothing else really matters very much.

Although, as Dr. Spittler has said, all accidental and war wounds are contaminated and potentially infected, the degree of contamination varies widely, as does the local and general resistance. The ideal treatment of such cases consists, as he says, of thorough debridement and mechanical sterilization, with primary or delayed primary suture. However, the use of any chemical antiseptic injures tissues as well as bacterial invaders, and is to be deprecated, though it is sometimes necessary.

In my professional lifetime a number of different antiseptics have been introduced and have been highly praised which later either have gone out of use altogether, or have been less employed. I believe the present uncritical enthusiasm for the use of the sulfa drugs will go through the same cycle, and that they will later enjoy a more limited and a more discriminating use.

Every recent article on wounds refers to the amazing results secured after the battle of Pearl Harbor, and the reports of Dr. Ravdin and Dr. Long are much quoted. They give a large measure of credit for these results to the lavish use of the sulfa drugs in the wounds.

In my opinion, there were many other factors which must equally well be involved in the explana-

tion of these results. The patients were a selected group of healthy young men in excellent physical condition and exceedingly well nourished. They were rested, not exhausted. They were clean. Even though they became smeared with fuel oil and soot and were filthy from an aesthetic standpoint, these substances are surgically relatively clean. They were not weakened by exposure to the elements for long periods; their wounds and clothing were not soiled with mud and dirt from cultivated and manured fields; and there was no long interval between the injury and the institution of surgical care. On the contrary, their hurts were attended to very promptly indeed. Finally, and most fortunately, at the U.S. Naval Hospital, on the U.S.S. Solace, at the U. S. Naval Mobile Hospital No. 2, and at the Tripler General Hospital were a large number of extremely competent and well trained surgeons, both regular and reserve—and, at the latter, civilian as well. All these factors should be considered in any evaluation of the treatment of the Pearl Harbor wounded, without undue emphasis being laid to any one factor alone. Moreover, I think Pearl Harbor was a special case, with conditions present that are not likely to be repeated.

War wounds differ from other accidental injuries only in the large numbers that are likely to occur simultaneously, and in the factors of exhaustion and exposure that are likely to be present. If they can be treated during the stage of contamination, debridement or mechanical sterilization is best, without drugs. If this "golden period" is lost then chemotherapy, local and general, is of service, but it should be used with discrimination and carefully, as an adjunct to good surgical judgment, not as a magic cure-all.

In substantiation of my opinion that good careful surgery is the most important preventative of infection in wounds, I report the following facts.

On December 7, 110 casualties were received at Mobile Hospital No. 2, where I was at the time in charge of surgery. These comprised a variety of burns and wounds, some of them of considerable extent. Sulfa drugs were used in only one case, a superficial laceration, and it became infected. It was the only infection that developed in the whole group.

I was loaned to the Naval Hospital at Pearl Harbor, and stayed there about thirty-six hours. I operated on about 25 cases. I used a sulfa drug in only one of them, a man whose cecum had been badly lacerated by a bomb fragment. Although I could not care for these patients personally, being recalled to my regular post, I have been informed by Captain Frank Ryan, at that time executive, and by Dr. Paul Spangler, my successor at Mobile Hospital No. 2 and at that time on the surgical staff at Pearl Harbor, that all my patients did well.

Furthermore, during the battle of Midway, three weeks ago, the ship on which I am at present serving proceeded to sea and took on board sixty casualties from the battle, among other people. Most of these were severely wounded. Many, not all, had had a little sulfa drug before they came under my care, but it was stopped at once, as I thought it unnecessary, except in one man who was suffering with gas gangrene when I received him. All of these patients, without exception, improved while on the voyage home and no new infections developed. When I saw them a week later in the hospital, they were continuing to improve, although I do not know what treatment they had had after leaving my care.

Shock

C. T. Young, lieutenant colonel, m.c. u.s.a.*

Shock is a profound depression of the vital processes characterized by reduction in volume of the circulating blood, poor tissue oxidation, vaso-constriction and rapid change in the relative proportion of the various blood elements. Briefly, shock is, according to Harkins, a progressive vasoconstrictive oligemic anoxia.

Cause

Theories as to the cause of shock are numerous. The most popular theories, briefly, are as follows: (1) the toxemia theory, in which the causative agent has been regarded at various times as either autolysates of muscles, toxins from damaged tissues, products of cellular disintegration, or toxic nitrogenous substances from traumatized muscles; histamine liberation resulting from injury of tissues has long been regarded by some as a cause of shock; (2) the theory of oligemia, from whatever cause, first promulgated by Sherrington and Cobbett, had many followers for years; Blum and Cannon insisted "shock is hemorrhage" and "hemorrhage is shock"; (3) the neurogenic or reflex theory of Goltz, Keen and Mitchell has been in the foreground at various times; sympathetic-parasympathetic imbalance, advocated by Mueller and others, has had its followers; adrenal gland exhaustion has been popular at various times, and is at present—Blalock speaks of adrenal gland exhaustion as being an ineffectual attempt to oppose histamine effects.

In primary or neurogenic shock, reflex vasodilatation, or increase in the size of the vascular bed, is the most important initial change. The vasovagal mechanism is probably responsible. It usually occurs immediately after the injury. It is seen also with the use of spinal anesthetics and in operations on the brain or spinal cord, or in operative procedures which involve pulling on the mesentery or peritoneum. It is usually temporary and responds well to vasoconstricting drugs. In secondary (which is known by some as hematogenic) shock, the most common type among battle casualties, a decrease in the volume of circulating blood plays a primary role. Vasoconstriction occurs early in this condition and only terminally is there vasodilatation. Evidence of this sometimes is not apparent for several hours.

Normally many factors influence the amount of fluid in the body and a normal partition of this total water among the tissue cells, the extracellular spaces and the vascular system. The intake of water and electrolytes must keep pace with the loss of these elements from the body. There must be sufficient plasma protein to hold an adequate volume of fluid in the blood stream. In hypoproteinemia there is a reduction in ability to hold fluid in the blood stream, so the escape of pathologic amounts of fluid to the tissues occurs. An additional factor, which is becoming of increasing importance according to Meakins, is the selective permeability of the capillaries which allows water and crystalloids to pass freely but holds most of the proteins in the blood stream. Whether increased permeability of the capillaries is the fundamental reason for the reduction of the effective blood volume resulting in shock is still controversial. Some investigators believe mechanical, chemical or thermal trauma also may initiate liberation of some substance that results in increased permeability of the capillaries. Oxygen lack is regarded as a more likely cause of this altered permeability by Black. Meakins insists that abnormal capillary permeability is a common denominator of the shock syndrome regardless of the initiating factors.

In the reduction of blood mass, the blood serum transudes through the capillary walls into the tissues, so that the blood in the vessels is concentrated considerably. With the hemoconcentration a higher red cell count results. A marked leukocytosis with preponderance of polymorphonuclears is often seen during the first few hours. There is in some instances 50 to 65 per cent reduction of the normal volume of blood. Since the loss at first is mainly one of water and salts, both the plasma proteins and cellular elements of the blood become more concentrated at first. However, when plasma loss really starts, together with electrolyte change, a reduction in the colloidal osmotic pressure of the remaining blood occurs and a reduced ability to draw on the extravascular reserve follows.

Blood Concentration And Other Changes

There is variable blood concentration in various types of shock. Following hemorrhage there is an immediate marked drop in both cell and plasma volume, but after physiological adjustment and redilution, the plasma volume increases rapidly. There is very little change in hematocrit at first. The cells remain quantitatively about the same. The hematocrit is quite low after redilution. After burns the

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cellular elements remain the same quantitatively but the plasma volume decreases rapidly, as in hemorrhage. The hematocrit rises at first but after redilution it usually returns to normal. Immediately after the usual type of accident where there is very little blood loss, there is mixed blood and plasma loss. A slightly higher hematocrit is the usual finding thereafter but after redilution it falls below normal, not as greatly, however, as after hemorrhage. The above illustrates that hemoconcentration cannot be used as the only guide to treatment. Physiological adjustments help for a short time, even without therapy, to cushion the effects of injury.

Massive loss of whole blood through hemorrhage may promptly reduce the blood volume to an amount incompatible with sustained circulation. The blood pressure fall results from the reduction in blood volume. In the terminal stage of secondary shock the vasoconstriction stage finally passes, followed by vasodilatation. This latter change, as well as blood volume changes, are reflected in the blood pressure. Blalock says peripheral circulatory failure, resulting from a discrepancy in the size of the vascular bed and the volume of intravascular fluid, is the chief manifestation of shock. When the blood volume is reduced, there is decreased cardiac output. There is an excess of blood cells in the capillaries with resultant congestion and increased viscosity of the blood. Oxidation is much reduced, as proven in animal experiments by Ault and Cunningham, and with the consequent lack of oxygen in the tissues, non-respirable acids, such as lactic and diacetic acid, replace carbonic acid. Lack of oxygen profoundly affects the nerve cells and disturbs their function. To maintain oxidation of the body tissues, a minimal systolic blood pressure of about 80 mm. of mercury is required. This so-called critical level marks the blood pressure level below which there is cessation of adequate flow of blood to the tissues. Anoxia causes marked depression of metabolic processes of the body as a result of which heat production drops off, sometimes as much as 65 per cent. The CO_2 combining power of the plasma drops often with a serious reduction in alkali reserve; acidosis is produced. Evidence of hyperpnea appears when the CO_2 combining power falls below 40 per cent. Another chemical change in shock sometimes seen is an increase in the N.P.N. and creatinine, and a drop in sodium and chloride content. Potassium is usually slightly increased.

It has been observed significantly in animals that a perceptible fall in blood pressure sometimes occurs only a short while before death; however, the plasma volume, the plasma protein concentration and hematocrit showed much earlier changes. In spite of the very early loss of plasma proteins and fluids, electrolytes and the consequent reduction in blood volume, the blood pressure at the end of six hours in the experiments conducted by Blalock was only slightly lowered. The vasoconstriction, it has been shown, aids in the maintenance of the blood pressure at its normal level despite marked plasma volume reduction.

CLINICAL EVALUATION OF SHOCK

The classical symptoms of shock are well known; cold, moist, sweating skin; thirst, vomiting, restlessness, mental dullness, reduced sensitivity to painful stimuli, apprehensiveness, etc. Objectively the patient may appear dehydrated, cyanotic, pale, perspiring, with a rapid thready pulse and in the latter stages a low blood pressure. Blood pressure determinations give a better index to the condition of the circulatory system than do pulse checks. The blood pressure, taken frequently, should be recorded.

Time does not permit the description of the falling drop method of Barbour and Hamilton but the information gained from its use is considerable. Those interested are urged to familiarize themselves with this procedure. If too many cases in shock do not have to be cared for at once it can be used to advantage in evaluating the status of battle casualties.

Meakins says "the beginning and progression of shock is best detected by frequent and accurate estimations of hemoglobin or by the hematocrit. A rising hemoglobin percentage or an increase of cells to plasma ratio indicate hemoconcentration due to loss of plasma through the capillary walls. This is probably the earliest indication of shock."

Black (Year Book of Therapeutics, 1941, page 240) gives a formula by which the blood volume may easily be calculated. For approximate calculation of plasma volume deficit, one is justified in assuming a hemoglobin percentage of 100 and a blood volume of 5 liters, 3 of which are plasma. The table below gives *trend* of change in plasma volume providing there is no hemorrhage.

Estimation of Plasma Volume Reduction Based on Formula by Black

Hemoglobin Percentage (Haladine)	Blood Volume (L.)	Plasma Volume (L.)	Estimated Deficit in Plasma Volume (cc.)
100	5.0	3.0	----
105	4.75	2.75	250
110	4.55	2.55	450
115	4.35	2.35	650
120	4.15	2.15	850
125	4.0	2.0	1000
130	3.85	1.85	1150
140	3.55	1.55	1300
145	3.45	1.45	1450
150	3.35	1.35	1550

These laboratory procedures are relatively easy to perform and can be done expeditiously. If there are a large number of battle casualties, there may not be time for these determinations, but the physician should grasp every opportunity to avail himself of these aids. The criticism may properly be made that such technical procedures have no place in a system where time is such an important factor. Very definitely, clinical judgment must be relied upon to determine the necessity for immediate treatment, rather than reports on above technical procedures.

TREATMENT OF SHOCK

The treatment of the condition causing the shock—as, for instance, control of hemorrhage—is the first prerequisite. Restoration of body temperature by use of blankets, guarded hot water bottles, or other means, is vital. Too much warmth is to be avoided. Relief of pain and restlessness by morphine is important. Large doses, however, reduce the oxygen interchange in the tissue, and the respiratory rate. Absolute rest in supine position is important. In early shock with vasoconstriction, the posture may be relatively unimportant, but the lower part of the body should be raised as soon as the condition is suspected anyway. Coramine and metrazol are good cardiac and respiratory stimulants and should be used as occasion demands. The use of vasospastics, such as adrenalin, can be harmful, though if used slowly and with care they can be an aid. Slow injection is mandatory. In neurogenic or primary shock vasospastics are particularly good.

Intravenous physiologic saline, or even at times hypertonic saline solution, to relieve the electrolyte and fluid depletion, is vital. In patients suffering from shock an overdose of fluid can be dangerous. Black, of Oxford, states the danger is less with protein-containing infusions than with saline. Oral and subcutaneous fluids are of much less help. Glucose has relatively little value compared to physiological saline. Blood plasma, which contains the vital proteins of the blood, can be administered immediately and this is an important advantage. Dried human plasma which can be put into solution quickly and which is always immediately available in all our medical installations, represents our best source of intravenous fluid. Because of the vital proteins in the plasma it is superior to the saline, though electrolyte replacement must not be overlooked.

Time does not permit discussion as to relative value of concentrate and dilute plasma. Blood transfusion is valuable to restore blood volume and likewise to replace proteins, but the cellular elements are not needed nearly so much as the proteins in the average case of shock. Where there is serious loss of blood due to hemorrhage, transfusion is usually to be preferred. Volume for volume, plasma transfusions introduce protein even more rapidly to the blood stream than when whole blood is given. There is also less danger from reaction than when blood is used. Blood plasma and serum adequately restore depleted blood volume and serum protein deficiencies. In traumatic shock, the initial dose of plasma can be as high as 750 cc. and as much as 2500 cc. may be required the first twenty-four hours after injury, with 1000 cc. daily for three days. In extensive burns, 2000 cc. of plasma may be needed the first twenty-four hours with 1000 cc. daily for three days. Whole blood is indicated after the third day.

Whole blood and plasma should be given early if there is shock due to hemorrhage. Water cannot be retained in the body without sufficient salts to make an isotonic solution. Any attempt to restore water alone is unsatisfactory. Sodium and chlorides are both depleted and must be replaced. If much vomiting has taken place, the chloride is particularly depleted. Isotonic solutions are usually used.

If there is increased capillary permeability, the introduction of aqueous solution dilutes the plasma further and increases the capillary permeability, so tissue edema is accentuated. Measurement of hematocrit or hemoglobin determinations are the best means of following this. If fluid is being retained in the blood stream, hemoglobin and plasma protein should decrease in concentration together. When hemoglobin is increasing and plasma is decreasing the plasma is being lost from the blood stream. It may sometimes be advantageous to give hypertonic solutions to avoid giving too much fluid in the vein. Ringer's and Locke's solution can be used advantageously.

Adrenal cortical extract (eschatin) is presumed to influence the permeability of injured capillaries. Its use with 5 per cent salt solution is claimed by Scudder to be helpful in severe cases of shock. As chloride retention occurs in patients given adrenal cortical extract, Rhoades, Wolff, and Lee say that salt solutions should not be given concomitantly unless chloride determination is done. However, as capillary permeability is reduced, plasma can be afterwards given to greater advantage. Adrenal extract, according to Helfrich, is more effective if given prophylactically than if given after shock has already appeared.

Oxygen is one of the best cardiac stimulants known for patients with anoxemia. It can be given by B.L.B. mask, by tent, or by nasal catheter. The establishment of a method to give large numbers of patients oxygen is now in progress by use of multiple outlets from a line carrying oxygen under pressure. The outlets are connected to bubble bottles through which the oxygen passes to the masks. Each patient in the shock room or ward with this arrangement receives oxygen as needed.

The ideal arrangement is to have a special shock ward where each of the attendants has had special instruction and where the set-up permits rapid evaluation of the status of the patient in shock with the necessary treatment given quickly and as long as his condition requires it. Without such an arrangement the treatment is apt to be haphazard and ineffective.

SUMMARY

The cardinal changes taking place in an individual in shock are vasocontriction, anoxia, alteration of capillary permeability, hypoproteinemia, oligemia, and reduced colloidal osmotic pressure of blood. As a result of above changes, there are hemoconcentration, capillary congestion, diminished blood flow, and decreased cardiac output. Depressed metabolic processes naturally follow such changes.

The main treatment of shock can be summarized as follows: (1) Treat early, even though evidence of shock may not be clinically apparent. (2) Keep patient at absolute rest, with elevation of foot of bed. (3) Apply warmth to the body. (4) Adequate fluid replacement is important, therefore use plasma early and in adequate amounts. (5) Transfusions. (6) Crystalloids, physiological sodium chloride, Ringer's or Locke's Solution intravenously. (7) Cardiac stimulation. (8) Oxygen as needed. (9) Judicious use of sedation, especially of opiates, sufficient to control pain only. (10) Adrenal cortical extract.

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DISCUSSION

DR. S. E. DOOLITTLE: I appreciate the opportunity of reviewing Colonel Young's paper on shock. With memories of December 7 still fresh in mind, it is indeed a timely subject.

The numerous concepts of the underlying pathological physiology of shock and attempts to differentiate various types of shock have always been confusing to me. From the various theses concerning experimental and clinical shock there stand out certain important pathological physiological changes noted by all critics. The most important of these have been re-emphasized by Dr. Young; namely, strong sympathetico-adrenal activity, increased capillary permeability, hemoconcentration and tissue anoxia.

In war wounds, the clinical pictures presented to the physician is rarely that of uncomplicated shock. The state of peripheral vascular failure caused by shock is further augmented by other neurogenic factors (fear, exhaustion, or exposure), by hemorrhage, or by other vital organ damage or disease.

The principles of treatment aim at control of complicating factors as well as of shock itself. Thus the control of hemorrhage, of fear, and of pain are of primary importance. Morphine is the drug of first importance in the treatment of shock. Adrenalin is a dangerous drug. The shocked patient, as I saw him on December 7, is an overadrenalized patient. Cortin, as Dr. Young suggests, is perhaps better to prevent than to cure shock. It, may however, be of assistance in preventing progression of the condition if given early and repeated frequently. Plasma is the main stop to capillary leaking. It should be given early and in sufficient quantities. If in doubt, and laboratory aids are not available, give more. Whole blood is also needed when hemorrhage is a complication. *Do not forget oxygen.* Much of the damage is due to tissue anoxia and a well oxygenated blood will lessen tissue anoxia.

Abdominal War Wounds

L. D. Heaton, lieutenant colonel, m.c. u.s.a.*

The patients we have seen with abdominal wounds are invariably in a rather marked degree of shock when first seen on our receiving wards. The prompt relief of this shock is indicated before any attempt is made to determine the extent of the injury or the methods of choice in its repair. Plasma has become the sheet anchor in our treatment of this condition but we have not lost sight of the use of blood transfusions or saline and glucose infusions. No operative procedure is considered until shock is controlled, except where gross hemorrhage is felt to be the responsible factor.

When this shock has subsided we attempt to visualize the probable tract of the responsible agent in an effort to determine the structures most likely to have been damaged. If the wound is penetrating rather than perforating, which is most frequent, the use of x-ray will aid considerably in this step. Catheterization should never be omitted. The object of this visualization of the tract is to determine the most nearly ideal incision for exploration. Cases will be seen where the wound tract appears to be entirely extraperitoneal. We advise caution and careful observation for signs and symptoms of peritoneal irritation in this type of wound. We have had two cases in which the traumatic agent remained extraperitoneal throughout its course, yet laparotomy revealed ruptured small bowel in both instances. We therefore agree with Bailey that "it is better to open and see than to wait and see."

Operative Procedures

In the selection of anesthetics we have remained firm in our belief that open drop ether is superior to all others. Spinal anesthesia has no place in patients who are so prone to shock.

When we could demonstrate no special reason for a particular incision, we have used either a midline or a right paramedian approach. The incisions should always be made through clean untraumatized tissue, if at all possible. Adequate exposure has been a fundamental principle in all cases.

On opening the peritoneal cavity we first look for gross hemorrhage of such a degree as to demand primary consideration. We do this with minimal handling of viscera. So far we have not seen a single case where hemorrhage of this calibre was present, except in cases of splenic rupture.

When we are satisfied that no significant hemorrhage exists, we examine the bowel in a definite and systematic fashion. The colon is examined carefully, starting with the transverse portion. This is done first because of the degree of contamination resulting from perforations of this organ. If damage of the colon is found, it is repaired before examining other organs. We next examine carefully the small bowel from below upwards, inspecting its associated mesentery at the same time. Here, as in the colon, surgical repair is made, as the injury is localized so as to minimize contamination. The stomach and duodenum are then examined. Injury to the duodenum is rare, but stomach perforations are frequently found on the anterior as well as the posterior surface.

When the gastro-intestinal tract has been examined, we move on to a careful inspection of the solid viscera, bladder and retroperitoneal structures, if indicated. Splenic tears are not amenable to repair, and removal of the organ is usually preferred. Liver tears respond well to packing with gauze of almost any type. Sulfathiazole powder has been used, because of its reported hemostatic qualities. Sutures in the liver are employed only when necessary. Gall bladder and duct damage is best cared for by temporary measures of drainage. Pancreatic wounds, except for possible hemorrhage, are quite self-limited. We do not hesitate to explore or repair kidney or ureter damage by the transperitoneal route. We have performed nephrectomy by this route with excellent results. Bladder tears require simple suturing and indwelling catheters.

In general, when considering any gastro-intestinal wound, it has been shown that suture of perforations should be practiced whenever possible, rather than resection. In the colon we must not forget that perforations are often retroperitoneal and should not be allowed on this account to escape detection. Infarction and damage to the blood supply of the colon often demand drastic rather than conservative measures. Resection may be necessary in instances where damage is marked and in these cases a prophylactic cecostomy should be performed. The dangers of infection are so severe in some colon wounds that simple suturing should be supplemented

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with drainage, and even colostomy, without hesitation, if the operator feels it is indicated.

In the small intestine, resection is to be avoided if at all possible but if there is no alternative should most certainly be performed. The chief indications for such a procedure are as in the large bowel:

(1) where a section of the intestine has been destroyed;

(2) where multiple perforations in close proximity make healing unlikely;

(3) where injuries of the mesentery and its vessels endanger the vitality of the gut (a two-inch detachment of mesentery is judged to be in the danger zone).

Multiple resections are to be avoided, for the mortality is especially high. A short-circuit operation may be employed if obstruction is anticipated, but should not isolate long segments of gut as this may result in nutritional disturbances. We have employed the end-to-end technique for resections whenever possible. Side-to-side methods are quite satisfactory however, especially to avoid difficulty with an uncooperative mesentery. All our bowel closures and resections are done with gut and silk, employing the Connell, Cushing or Lambert stitches.

Duodenal wounds are relatively rare and we have had none so far on our service. Gastroenterostomy, or even partial gastric resection, may be necessary for satisfactory reconstruction. Stomach wounds may usually be sutured without difficulty.

In all abdominal wounds we have placed from 4 to 16 grams of powdered sulfanilamide intraperitoneally and over the suture lines at the completion of surgery. Drains or packs are brought to the exterior through stab wounds or through entrance or exit wounds after debridement, if they are in a suitable position. Our exploratory wound is closed tightly in layers and as a last procedure the entrance and exit wounds are debrided. Sulfanilamide powder and vaseline gauze are then inserted in the resultant tracts.

It might be well to mention that we have had a number of thoraco-abdominal wounds on our service, the majority of them with successful results in spite of their relatively lethal nature. In these cases we treat the chest conservatively, if possible, and if surgical intervention is necessary we attempt to make closed wounds out of those that are open. We repair the diaphragm, if it is at all possible to do so, and prefer a separate abdominal incision for exploration rather than the trans-diaphragmatic approach.

POST-OPERATIVE CARE

Our post-operative routine is like that practiced in most abdominal surgery, but it is necessarily more extensive. Parenteral fluids and morphine are given as required. The inevitable ileus is combated with continuous Wangensteen suction or Miller-Abbott tubes. Oxygen tents or masks are of considerable help in most cases and are indispensible in thoraco-abdominal wounds.

We never institute sulfa drug therapy for the first twenty-four hours following surgery. Adequate blood levels of sulfanilamide are maintained during this period from peritoneal absorption. Even if we find no special indication for sulfonamide therapy we continue it thereafter for several days as a prophylactic measure in suitable cases. We have found sodium sulfadiazine intravenously to be far superior to other sulfa drugs, particularly when oral administration is impractical. It necessarily must be used with caution, however. Blood levels of 5 to 13 mgm. per cent are to be maintained, and dosages governed accordingly. Oral dosages, when this route was feasible, have averaged 1 gram each four hours, and we have maintained this therapy for three to seven days post-operatively. Daily sulfonamide blood levels, frequent blood counts and urinalyses, are recommended. A urinary output of at least 1,000 cc. per day is essential when patients are on such therapy.

Blood transfusions and other supportive measures are given as indicated. Some anemia invariably follows such injuries and the sulfa drug therapy may aggravate this picture.

CONCLUSION

In summary, I have presented the methods used by the Surgical Service of the North Sector General Hospital in the handling of these grave abdominal wounds. Our results have been so gratifying that we heartily recommend all of these points for your consideration.

DISCUSSION

DR. JAMES R. JUDD: I am much pleased to have the opportunity of discussing Colonel Heaton's excellent paper, which is short and snappy and to the point, like a well performed surgical operation. The Colonel's conclusions are well drawn. I agree heartily with him that ether, by the drop method, is the safest and most satisfactory anesthetic for emergency war surgery and that spinal and intravenous anethesia have very little place in such work.

Colonel Heaton's conclusions are based on data obtained mostly from young healthy soldiers. It might be of interest to discuss the effects on civilians of this diabolical method of warfare, first started by the Germans when they bombarded Warsaw from the air in September, 1939.

In the September 1941 issue of Surgery, Gynecology and Obstetrics is an able article by Dr. Gordon-Taylor entitled "The Problems of Surgery in Total War," based on 600 abdominal cases, and I am quoting from this article especially as the facts therein bear on civilian casualties. Every hospital in London except two has been hit by air bombardment. The mortality of children and old people is high, although there have been some remarkable recoveries.

A considerable proportion of the casualties results from crushing force or from the direct or indirect effect of "blasts." In crushing injuries the abdomen is less exposed to damage than the head, shoulders or limbs, and in lesions due to "blast" the lungs are more vulnerable than the abdomen. In this war, civilians suffer from crush-contusions due to falling masonry and from burial under collapsed houses. Masses of wood, stone or metal may be hurled with devastating force against the abdomen; severe visceral damage or retroperitoneal hemorrhage may be produced by "blast" without any external evidence of injury. Frightful wounds have been produced by flying glass eviscerating the patient. These cases are mostly beyond surgical aid.

Multiplicity characterizes wounds sustained from air bombardment. Mortality is raised by lesions of several viscera and many parts of the body being simultaneously damaged.

Burns may be a serious complication of abdominal wounds and add greatly to the gravity of the prognosis.

Associated severe fractures, especially compound fractures, often turn the scale against recovery.

"Blast" injury of the lungs, by reason of the pain produced, may suggest the diagnosis of an abdominal lesion. Some of the patients have rigid abdominal walls. X-ray examination of the chest and the physical signs, especially bulging of the chest wall, should prevent an unnecessary laparotomy.

Abdomino-thoracic injuries in this group approximate 13 percent; the mortality of left-sided abdomino-thoracic injuries exceeds that of the right side by 20 percent.

Diaphragmatic injury is suggested by an almost entirely thoracic type of respiration with a catch at end of inspiration, yet the actual respiratory rate may be little altered. In later stages, there is fixed pain, exaggerated on exertion and referred to clavicle or scapula, according to the position of the injury.

In patients operated on, the rent in the diaphragm is usually small, less than half an inch long in 50 percent of the cases. Many openings are mere punctures. Wounds of tne central tendinous part are more serious than those of the periphery. Small wounds undoubtedly heal spontaneously and others are at least temporarily plugged by omentum, liver, stomach and spleen.

When there is an open blowing thoracic wound or an associated "stove-in-chest," the chest injury must assume priority of treatment.

If an abdomino-thoracic injury has been approached from the abdominal aspect, it is important not to waste time trying to complete a difficult suture of the diaphragm in a critically ill patient, unless the aperture is so large that a herniation of the abdominal contents is certain to occur.

CONCLUSION

1. Despite the gravity of the wounds and the frequent association of multiple injuries, about 50 percent of the patients with abdominal injuries for whom operation is possible, survive.

2. The percentage of recoveries for injuries to the gastro-intestinal tract is higher than in 1914-18. For the large intestine it is about the same.

3. Few survive after lengthy resections of intestine.

4. The employment of sulfonamides locally and by oral administration has proved of great value.

5. Transfusion of blood and its derivatives has made a host of patients operable who otherwise would certainly have died.

Chest Wounds

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Because of its size, exposure and vulnerability, trauma to the chest plays an important part in a consideration of war injuries. It has been estimated that well over one-third of all fatalities in combat are due to injuries to the chest, and that chest injuries are second only to abdominal injuries in their seriousness.

I am fully cognizant of the fact that many serious injuries of the chest wall and enclosed organs result from trauma that does not cause an opening into the pleura. These injuries are to be discussed by others on the program and will not be considered here. The fact should also be appreciated that an individual having an injury to the chest may have injuries elsewhere as well, and a thorough examination should be made to avoid overlooking such complications.

Pathologic Physiology

In a discussion of chest injuries it is important to remember a few physiological principles that make the care of such lesions a problem differing from the care of injuries encountered elsewhere. All the organs of the thoracic cage carry on their work under a pressure which is intermittently less than that of ordinary atmospheric pressure. Hence, an opening into the pleura results in collapse of the lung at a rate depending upon the size of the opening. The collapse of one lung would not ordinarily result in serious interference with the cardio-respiratory mechanism were it not for the fact that under such conditions the mediastinum and its structures are usually displaced toward the contralateral lung. Thus an opening into one pleural cavity seriously affects the organs concerned with the vital functions of respiration and circulation unless the mediastinum has become stabilized from previous inflammatory changes.

First Aid Measures

The first aid treatment of chest injuries may be extremely important, first, in the control of hemorrhage, and second, in the case of so-called sucking wounds. Bleeding is usually from one of four sources. It may be from an intercostal or from one of the internal mammary vessels. In either instance the vessel may or may not be easily ligated. The bleeding may come from the lung, in which case spontaneous cessation is to be expected, unless one of the larger vessels is involved, because of the low pressure in the pulmonary circulation. The bleeding may be from one of the vessels in the mediastinum, from one of the vessels in the hilum of the lung, or from the azygos veins, in which case control is difficult, and a fatal outcome is likely before the patient can be transported to a place where adequate surgical interference can be instituted.

Many people who lose their lives when an opening is torn into the chest wall could be saved by the very simple expedient of plugging the hole with anything that can be stuffed into it—sterile moist gauze or sterile vaseline packs—or by using the simple apparatus illustrated herewith. Time may be the essence of success, however, so peel off your shirt and use that; or place your hand over the opening; or use any suitable object or material—sterile or unsterile—to seal over the opening.

Strapping the patient's chest with adhesive in the presence of fractured ribs may relieve that patient's pain and help to prevent shock. The liberal use of morphine, if the patient's respiration is not embarrassed, is of value. Shock, of course, is to be combatted by the various methods at our disposal after the patient is hospitalized and before surgery is undertaken. The free administration of oxygen is of particular value.

In penetrating or perforating wounds of the thoracic cage which do not result in open pneumothorax, emergency surgery, except for the control of hemorrhage, is rarely indicated. In civil life, such wounds are commonly produced by stabs from a knife or ice-pick or from a rifle or pistol shot; in the military service, by fragments of high-explosive missiles. In such injuries, signs of accumulating blood in the pleura should be watched for, and when found should be aspirated and replaced by an equal amount of air. Blood left in the pleura invites infection; it is slowly absorbed; and it irritates the pleura, causing it to become thickened, and thereby inhibits lung re-expansion. Air, on the other hand, acts more as a compressible cushion and causes little or no pleural irritation.

TENSION PNEUMOTHORAX

In any trauma to the chest in which the lung, bronchi, or trachea is injured, air in varying amounts may escape into the pleura, subcutaneous tissue, or mediastinum. If with each inspiration air is drawn into the pleural cavity and on expiration it cannot escape, a tension pneumothorax will be produced. This may, when carried to a sufficient degree, result in complete collapse of the affected lung, and so embarrass respiration and circulation as to result in asphyxia of the individual. The symptoms are increasing respiratory difficulty, cyanosis, and signs of shock. The physical findings show hyperresonance over the affected side, distant or absent breath sounds, and displacement of the heart away from the side involved. The x-ray picture, if available, substantiates the clinical findings. The treatment consists of aspirating the air from the pleura until the pressure is zero, or of inserting a catheter intercostally into the pleural cavity. The lower end of this catheter is sealed by connecting it with a rubber tube which is inserted into a bottle containing fluid beneath the bed.

Air escaping into the mediastinum in a similar manner may build up so much pressure that it may interfere with circulation or interfere with respiration by pressure on the trachea or major bronchi. A suprasternal incision into the superior mediastinum may give relief, though usually some grave mediastinal injury has already occurred and results in a fatality.

SURGICAL PROCEDURES

In the repair of open chest wounds, pressure anethesia is almost indispensable. If it is not available, aspiration of the air in the chest following surgery is important to allow re-expansion of the lung.

If circumstances permit and the patient's condition justifies it, pre-operative x-ray study of the chest to locate foreign bodies is desirable. Wounds in this region should be thoroughly debrided as elsewhere. Foreign bodies should be removed, and blood clots and debris should be sucked out of the pleural cavity, either through the original or enlarged wound or through a new approach if the patient's condition justifies it. From 8 to 10 grams of powdered sulfanilamide should be dusted into the pleural cavity and into the wound itself, and the chest wall closed tightly if possible. I believe it is desirable to place a water-sealed catheter into the chest of all such injured individuals. It would seem wise to place a No. 18 F. catheter in the second and third interspace in the midclavicular line, since there is less likelihood in this locality of the catheter's becoming plugged by blood or kinked by the patient's lying on it. This, I believe, should be routine since no hospital that I know of in the Territory would be sufficiently staffed to watch carefully for the onset of tension pneumothorax, if we were suddenly called upon to treat a large number of wounded.

POST-OPERATIVE CARE

When the patient is returned to the ward he should be closely watched for signs of hemorrhage, for signs of tension pneumothorax—if a water-sealed catheter has not been inserted—and for onset of shock. If fluid accumulates in the chest, it should be aspirated and the fluid smeared and cultured, and the patient watched for the possibility of infection. Lung abscess from embedded foreign bodies in the lung may occur and should be anticipated.

CARDIAC INJURIES

In passing, mention should be made of injuries to the heart. Most of them are immediately or soon fatal and are not amenable to any type of therapy. Occasionally injury to the chambers of the heart or to the great vessels at its base permits leakage of blood into the pericardial cavity slowly enough to allow successful surgical intervention if the condition is recognized without delay.

Blood accumulating in the pericardium interferes with expansion of the heart, and like the effect of accumulating air in the pleura on the lung, soon renders the heart incapable of functioning. This condition of tamponade of the heart causes cyanosis and respiratory difficulty, diminution in volume of the pulse, weakening of the cardiac sounds, fall in systolic blood pressure, increase in venous pressure, diminished activity of the heart as seen under the fluoroscope, and death in short order if the condition is unrelieved.

CONCLUSIONS

In concluding these brief remarks I want to emphasize:

(1) The importance of the first aid treatment of so-called sucking wounds of the chest. Plug the hole immediately by one of the methods suggested.

(2) Control hemorrhage from the intercostals or internal mammaries by ligation or compression.

(3) Watch out for tension penumothorax. Aspirate if in doubt. Insert water-sealed catheter when necessary.

(4) Aspirate blood from the chest and replace it with air.

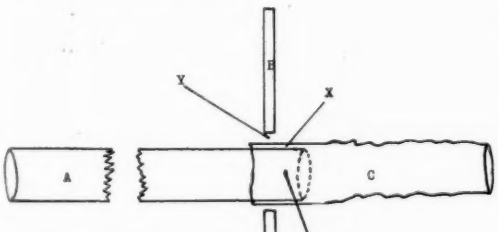
(5) Treat shock in chest injuries as elsewhere before subjecting patients to surgery.

881 Young St.

DISCUSSION

DR. FENNEL: The "thorax valve" mentioned by Dr. Strode serves to seal a small penetrating wound of the chest, or a large, lacerated blowing one, permitting egress of air and fluids, and preventing ingress of air, thus stabilizing the mediastinal contents. It is easily extemporized from available materials, which is a most important feature.

To make such a thorax valve, take a 6 inch length of rubber tubing—anything from a small catheter to a tube of ½ inch inside diameter, depending on the type of wound anticipated. Clean 1 inch of one end with gasoline, xylol or sand paper and apply rubber cement, which is allowed to dry. Take a piece of cleaned auto tire inner-tubing anywhere from 4 to 6 inches square, or rectangular (or larger) and with a cork borer cut a round hole in its center. This hole is to be *definitely* smaller than the outside diameter of the rubber tube that is to enter the thorax. Anoint this hole with rubber cement and permit it to dry.



A—Rubber tube or catheter.
B—Rectangle of inner tube rubber.
C—Condon, cemented to tube.
X—Rubber cement.
Y—Optional rubber cement.
Z—Site for insertion of safety pin.

Stretch the closed end of a condom over the open end of a large test tube and with a hot wire, make a hole in the condom. This hole will have a sticky, gummy edge. By careful stretching of the perforated condom, pull it over the cleaned and cemented end of the rubber tube, to a distance of about ½ inch, letting it contract there. Now pull the bulk of the condom toward the other end of the tube. Apply a little additional rubber cement to the cemented end of the tube, pull the condom back over this area, hold it in place with a rubber band or several windings of twine and give it time to set.

Have an assistant stretch the inner-tube rectangle until the central hole is large enough to admit the tube, with attached condom, and slip the tube through until, on contraction, the inner-tube square firmly grips the end where the condom is cemented. Additional rubber cement may be applied at the junction.

The distal, reinforced end of the condom is cut off with a scissors; because of its collapsed condition, it acts as a flutter valve. A safety pin, through the wall or even the lumen of the distal portion of the tube will prevent the loss of the tube into the pleural space. After the cement is set, this gadget may be sterilized in formalin vapor, or, placed in a jar, may be autoclaved.

For use, the long end of the tube is cut to desired length—it may be fenestrated—and inserted in the pleural wound, the edges of the square of inner tube rubber are affixed to the skin with strips of adhesive. Duco cement, if available in the emergency, would be additionally effective.

This simple apparatus relieves compression of the mediastinum by air or fluids and leaves the patient mobile without need of a special attendant.

DR. H. H. WALKER: Dr. Strode has dealt with the immediate treatment of chest wounds in a concise and able manner. Thoracic wounds in modern warfare are prone to be of very serious nature and carry a high mortality rate. The injury may be of such magnitude as to preclude any chance of survival. Others, however, may have a good chance if there is not too great delay in receiving proper medical and surgical treatment. The first-aid treatment received by the patient in a casualty station is frequently of far greater importance than the late operative treatment in deciding the final outcome. The treatment of shock and hemorrhage always, of course, should be given first consideration. Secondarily, or in many instances simultaneously, attention should be directed to the restoration of cardio-respiratory physiology to normal. The patient should be placed in the position affording the greatest comfort—usually semi-sitting. Morphine should be given with the utmost caution and oxygen administered if available. Sucking wounds must be plugged just as quickly as possible. The valvular contrivance described by Dr. Strode and Dr. Fennel would be a good thing to have handy in any casualty station. However, the important point is to plug the wound. External bleeding should be controlled as expeditiously as possible with the least amount of disturbance to the patient. If ribs are fractured, adequate immobilization will be secured by strapping the hemithorax.

One must always be on the alert for a pneumothorax, hemothorax, or hemopneumothorax in the presence of an injury to the chest. Signs may not be evident at the first examination so that these patients must be watched carefully for several hours. It must be remembered that an individual supposedly suffering from shock or a blast injury may also have a tension pneumothorax or hemothorax. A portable x-ray machine when available should be used to establish the diagnosis. However, physical examination of the chest will usually reveal the underlying condition. Of the physical signs, cardiac displacement is the most important. Dr. Strode has described the treatment for pneumothorax and hemothorax. I believe that waterseal drainage is the most foolproof method of dealing with tension pneumothorax. Likewise, I agree thoroughly with Dr. Strode that the blood should be aspirated in the case of hemothorax.

Operative surgery in thoracic wounds, especially in the case of foreign bodies, should be delayed, in my opinion, except when it is necessary to close a sucking wound or when it becomes obvious that intra-thoracic hemorrhage is progressive.

Head Injuries

RALPH B. CLOWARD, M.D.

Honolulu

Few subjects in medicine have produced so much controversy and stimulated so much writing as the subject of head injuries. It would be futile to even attempt to touch upon the anatomy, the pathologic physiology of the various types of wounds, the complications and the divergent opinions on the treatment of cranio-cerebral injuries in this brief period of ten minutes. I shall limit this presentation to a brief discussion of the pathology and the accepted treatment of two types of head injuries most frequently encountered.

CONCUSSION

The first type of injury is that produced when the head, in motion, strikes an immovable object: for example, falls from high places, or automobile accidents. The pathologic changes in the brain that result are due to inertia of the intracranial contents. It has been shown experimentally that the brain has the physical properties of a liquid. When the head is set in motion and then suddenly stopped, a wave of force is transmitted through the brain. The movement of this wave causes a momentary gradation of pressure changes along its pathway, from a positive pressure at the point of impact to a negative one at the opposite pole. This negative pressure, being lower than the intravascular pressure, may result in a rupture of vessels on the side of the brain opposite the blow. This is the physiology of the so-called contre-coup injury. The bony pockets of the skull, into which the frontal and temporal poles are so closely fitted, make these areas of the brain much more susceptible to contusion in this type of injury.

The chief symptom resulting from this inertia of the brain is an instantaneous interruption of consciousness. This is due to a mechanical derangement of the molecules within the nerve cells, brought about by their acceleration. This may be so severe in some cells as to completely destroy them. The duration of loss of consciousness is the best index of the severity and extent of the cerebral damage. It may be momentary, or last for hours or days. The other symptoms, dizziness, nausea and headache, are the result of vasomotor changes in the brain. Increased intracranial pressure is not a part of the initial pathology. It may or may not develop later. When it does it is due either to edema of the traumatized brain, or an extravasation of blood into the extra-cerebral spaces, the brain substance itself, or both.

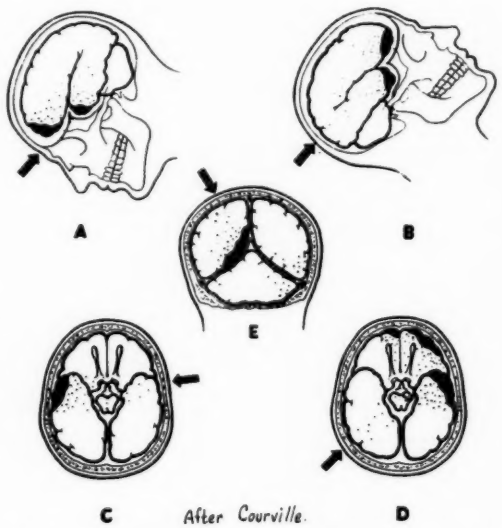


Fig. 1. The mechanism of cerebral concussion and contusion. Arrows indicate point of application and direction of force. Location of contusion: black; petechial hemorrhages: stippled.
A. Frontal injury giving fronto-temporal injury.
B. Occipital injury with fronto-temporal contusion.
C. Temporal lobe contusion from contralateral injury.
D. Fronto-temporal injury from blow to opposite temporo-occipital region.
E. Diffuse mesial temporo-occipital contusion due to blow on vertex.

It goes without saying that in the treatment of this type of head injury no standardized set of rules can be followed. Every case is an individual problem and its treatment will depend upon the extent and severity of the injury. The length of time the patient is unconscious may be used as a basis for a simple classification of these patients. They may be divided into two groups after excluding the small number who die immediately or within a few minutes of the accident:

Group I includes those patients who are dazed or who are recovering consciousness shortly after the accident.

Group II comprises patients who remain unconscious for approximately an hour or longer from the time of the accident.

In Group I, which fortunately represents about 85% of all head injuries, the old adage of "masterful non-interference" is the best treatment. By this we do not mean the patient should be neglected. On the contrary, he should be observed closely and frequently for the first twelve hours for any change in temperature, pulse, respirations, blood pressure and, particularly, the state of consciousness and ability to move the extremities. Any alteration in these functions may be a warning signal of rapidly increasing intracranial pressure due to hemorrhage. If the accident occurs at night, some one should be given the responsibility of awakening the patient every two hours. In the uncomplicated case the only treatment this group requires is absolute bed rest, with the head kept flat, for a minimum of ten days to two weeks. Aspirin for headache and a mild cathartic are the only medications necessary. The two weeks in bed for any patient who has been rendered unconscious should be insisted upon. Although it may seem an economic waste to the patient at the time it is the only sure prophylaxis against the development of the disagreeable "post-concussion" symptoms of headache and vertigo which so frequently follow these injuries.

It has been around the treatment of Group II, i.e. the patients who are unconscious longer than an hour, that all the controversy and divergence of opinions has arisen as to the correct methods of therapy. Dandy said, "Present day treatment of these patients, taken compositely, is a curious admixture of tradition, of scientific fact and of fallacies which pass under the cloak of science." This group represents about one-tenth of cases. In civil practice the injury is produced usually by the occiput's striking the ground. The patient is deeply unconscious. If the skull is fractured it is often through the base, with hemorrhage from the ear. The spinal fluid is bloody. A few of these cases will die within twenty-four hours from extensive brain damage and intracerebral hemorrhage — a hopeless sub-group. The remainder are hopeful but obviously seriously ill.

It is for the relief of increased intracranial pressure that the various more radical forms of therapy have been advocated. Dandy says, "Operate on 10% of them"—subtemporal decompression. Munro and his followers advise radical drainage of cerebrospinal fluid by frequent lumbar punctures. Fay leads another group who dehydrate the brain (and the patient) by limiting fluid intake, administering large doses of hypertonic solutions, glucose and magnesium sulfate, and doing lumbar punctures. All of these methods may have their merits in selected cases but not as a routine treatment. It has been definitely shown in many large series of cases that most of these patients actually have *no* increased intracranial pressure. Only about 5% will show really high pressures, the rest will be normal, or subnormal! It is only reasonable to conclude that these forms of treatment not only are unnecessary but may even do harm by interfering with the physiology of the injured cells, which are trying to stabilize themselves.

The following plan of treatment has been adopted by the majority of neurosurgical clinics in the country. The changes in temperature, pulse, blood pressure, etc., are closely followed as in Group I. A fast pulse and low blood pressure are grave prognostic signs. The case is almost hopeless if the temperature rises and respirations become irregular. Steadying pulse and blood pressure, smooth respirations and lessening of unconsciousness are encouraging. A free airway to permit unobstructed breathing is very essential. In other words, diligent nursing care is the essence of treatment in this group.

Fluids are administered in quantities sufficient for normal function of body organs at a basal rate, i.e., about 1500 cc. in the first twenty-four hours, 5 per cent glucose being given by venoclysis. If the patient is still unconscious after the second day, a nasal tube is inserted and high caloric liquid foods and fluids, 2400 cc. in twenty-four hours, are given. Vitamins and medication can be given through the tube. If the patient is restless and the cause is not due to a full bladder or a wet bed, it may be controlled by barbiturate drugs or paraldehyde given via the tube. Morphine or other narcotics should NEVER be given to a patient with a head injury! This is one of the most emphatic "nevers" in medicine. No lumbar punctures are done and no hypertonic solutions are given.

After three or four days, the patient may be still unconscious, semi-conscious and restless, or conscious and complaining of severe headache, and examination may show a stiff neck, a slow pulse and a slightly elevated temperature. These are the signs of blood in the cerebro-spinal fluid, and lumbar puncture is indicated. Marked relief is often given and the patient's condition is usually improved by removing 10 or 15 cc. of this bloody fluid. The procedure may be repeated daily until the fluid is clear.

The lumbar puncture may show a marked elevation of spinal fluid pressure with very little or no blood in the fluid. The neurological examination

may reveal progressive weakness of one side and possibly blurring of the optic nerve heads. This is indicative of either an acute edema of the brain, or a collection of blood in the subdural or extradural space. The patient is then taken to surgery and trephine holes made in the skull over the areas of the suspected hemorrhage, determined by the abnormal neurological signs that have developed, or by the site of a linear fracture seen in the x-ray. If a hematoma is found, it is evacuated. If none is found. the patient's condition is probably due to edema. Then, and not until then, should the use of hypertonic solutions be resorted to. Fifty per cent glucose, in 100 cc. doses given intravenously, will shrink an edematous brain and is of value when the existence of edema has been verified as described above. However, if it is given before the trephine holes are made, more harm than good may be done. If the brain is shrunk by the glucose, the subdural space is widened and an existing subdural hemorrhage may be increased.

In general, this plan of treatment is a very conservative one, but in the light of our present knowledge it is felt unwise to interfere with purposeful changes in physiology and pathology after trauma unless the indications are clear and definite.

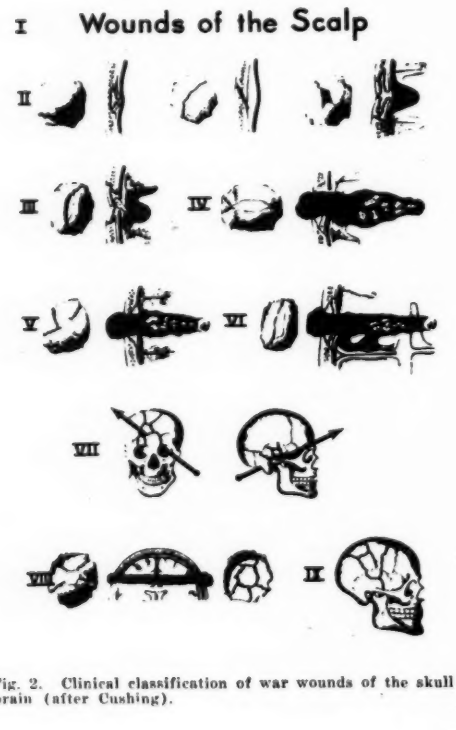


Fig. 2. Clinical classification of war wounds of the skull and brain (after Cushing).

TRAUMATIC WOUNDS

The second type of injury is that produced when the head (which is stationary) is struck by a moving object. The objects may be large, traveling at relatively low velocity, falling objects such as timber, stones, etc., or they may be small missiles traveling at a high rate of speed as bullets, bomb fragments and shrapnel[1]. The latter are the wounds most frequently encountered in war.

The pathologic changes in the skull and brain in this type of wound are altogether different from those in the first group. In these wounds the force applied to the head is concentrated in one area. The extent of the injury, of course, will depend upon the size, shape and composition of the missile, and particularly the rate of speed it is traveling. In general, one may say that the maximum injury to the head will be found at the point of contact of the missile rather than at a remote point as in the previous type of injury described. When the missile is very large and traveling at low velocity, the entire head may be set into motion, so that in addition to the local crushing injury produced by the missile there is added the "contre-coup concussion" with its symptoms of unconsciousness, etc. If, however, the missile is small and traveling at a high velocity, the head may be struck and perforated, and the brain penetrated, without the individual's even knowing he has been hit. An acceleration of the brain is not produced by such an injury; therefore, there is no interruption of consciousness. Between these two extremes all combinations of injury may be seen.

Most of the wounds produced in this fashion are compound depressed skull fractures. Their treatment is obviously surgical. The general principles in the surgical treatment of these wounds, as outlined by Dr. Harvey Cushing in the first World War are well known. A detailed description of the technique need not be given here; however, we may list the most important of these principles as follows:

1) Removal of all foreign material from the wound.

[1] The growing tendency even among military men to use the word "shrapnel" to mean any sort of flying metal fragment resulting from the detonation of a projectile is apparently going to result in an actual broadening of tthe meaning of the word. It originally referred, of course, only to the little lead balls, a centimeter or so in diameter, which were packed into projectiles along with a moderate charge of explosive which dispersed them violently on impact or at a predetermined interval after the shell had been fired. The balls were named after the man (Shrapnel) who invented them. Shrapnel was abandoned early in World War I because it was quickly discovered to be vastly inferior to "H.E." (high-explosive) ammunition. None has been used so far in the present war. When the word "shrapnel" is used, almost without exception, "bomb fragment" or "shell splinter" is meant.—Ed.

2) Careful debridement of all injured tissue, cutting the ragged edges of scalp and dura and removing with suction the damaged brain.

3) Complete hemostasis, using the high frequency electric current.

4) Tight closure of wounds, without drains. The large defects in the dura which cannot be closed are patched with periosteum or fascia lata.

5) Prevention of infection by thorough cleansing of wound at time of injury; early operation, within 6 hours if possible; generous use of sulfonamide drugs on the initial dressing, in the wound at time of surgery and by mouth ten days postoperatively.

6) Minimum of two weeks in bed.

7) Anticonvulsant drugs to be taken for at least a year after the injury.

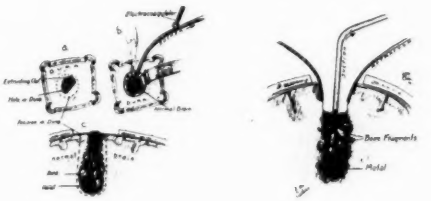


Fig. 3. Procedure for complete excision of the contaminated tract of brain by electrosurgery and the suction apparatus (after Horrax).

CONCLUSION

In conclusion we may predict that the mortality of head injuries as a whole will be definitely lowered if the principles of treatment as herein described are universally accepted and adhered to.

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DISCUSSION

LIEUT. H. HAMLIN, MC-V(S), U. S. N. R.: Dr. Cloward has shown an appreciation of the compensatory capacity of cerebral physiology to deal with traumatic insult. The primary objective in nonoperative care of head injury enacts a fundamental motive of good medical practice—to aid the natural processes of recovery. It is toward better results in the more serious cases, the second group described by Dr. Cloward, that our interest is directed. I add a few statements based on clinical experience with the methods he has outlined.

Increased intracranial pressure and cerebral circulatory deficiency are pathological effects usually associated with the variable combination of concussion—contusion—laceration of the brain. The logical purpose of treatment is to improve cerebral circulation and to restore normal brain volume. Elevated intracranial pressure may occur over a period of hours or days following the trauma and can be determined with certainty only by manometric measurement. Naturally there is no point in treating increased intracranial tension if it does not exist.

In general, however, multiple lumbar punctures with reduction of increased pressure and removal of subarachnoid red cells, if present, as often as indicated, and limitation of fluid intake to physiological need, has produced the best result I know of in patients with severe degree of injury—namely, a mortality rate of approximately 17% among several thousand cases (Boston City Hospital Clinic) and still more important, a lower percentage of post-traumatic symptomatology in follow-up observation.

The use of concentrated carbohydrate solutions and radical dehydration is not physiologically sound since it taxes an already overburdened vascular and metabolic state in a damaged brain. Roentgen study can usually wait until the patient's condition warrants transportation to the x-ray table. Surgery also in these cases is practically always elective, and like repeated spinal drainage, should be predicated only on definite clinical indications.

It is important to reiterate what has been said about acceleration in brain concussion. The experimental proof that this phenomenon is the principal factor responsible for massive disturbance of neurone function in head injury elucidates as never before the nature of its etiology. It is of small argumentative moment that the concept of molecular derangement of neurones remains a rather nebulous notion that has little correlation with our meager knowledge of the microscopic pathology, because an adequate explanation of the mechanics of a blow on the head has led belatedly to improved means of prevention. Methods to guard against rapidly augmented motion of the skull following a blow on the head are receiving greater consideration in the construction of our fighting machines and in the individual equipment of our fighting men. The same applies with equal importance to the field of civilian defense, in fact, to all human activity of the modern industrial era where the speed and power of a machine supersedes the adaptation of a conditioned reflex.

One of the chief contributions of the present war to frightfulness is the terrific speed and force of its explosive weapons. The aerial bomb, for example, causes cranio-cerebral injuries of a new and different character. In World War I men were concussed by relatively large and slow moving fragments which often compounded through the skull, carrying disastrous infection. In this war the effects of blast are causing us the greatest concern, but paradoxically, the central nervous system appears to be less vulnerable to its destructive force than other organ systems.

Dr. Palma has asked me to discuss the neurological aspect of blast injury. One must first remember that individuals exposed to blast may be thrown against objects or be struck by falling debris, thus sustaining the usual types of head injury. Reliable history is often unobtainable and such injury may be obscured by blast effects on lungs or viscera. Neurological appraisal, therefore, must be done with great care and morphine used with caution.

We shall consider the sailor who was blown through the side of a wooden ship along with his cabin and bunk. Unconscious for four hours, he

remembered the explosion clearly and had no headache or other neurological complaint on recovery but sufficient blast effect, in addition to the lesions demonstrated by x-ray, to cause subcutaneous emphysema of the upper thorax and neck. He did show nystagmus and a bilateral Babinski response when examined twenty-four hours after the incident and these signs disappeared in ten days, but the usual sequelae of brain acceleration were conspicuously absent despite the long period of unconsciousness.

Another man was close enough to a 500 lb. bomb explosion to receive flash burns of the face and neck. His trunk up to the scapulae was partially sheltered by structures surrounding his battle station and his back was toward the blast which he recalls vividly, including the Jap plane that delivered it. In contrast. brain concussion from a solid blow produces amnesia for events preceding the impact, which is an important index of severity. Unconscious for forty-eight hours, this man was treated for shock and given sulfathiazole during sea rescue. Numerous tiny bomb splinters are present throughout the brain and their external perforations can be matched. There was a quadriplegia in extension on admission with complete sensory sparing which has improved to a state of hypertonic paraplegia. Subarachnoid hemorrhage was present and markedly increased intracranial pressure which has gradually subsided. The chest and abdomen were protected from the explosion. His recovery has been amazing. Some acceleration of the brain had undoubtedly occurred, but that the nervous system can survive such an enormous blast is miraculous unless we admit that the force exerted by its complicated pressure system, however powerful and quixotic, has a different and a less damaging effect on the skull-encased brain beyond a certain fatal range than does a solid blow. The kinetic properties of the latter would seem to be negligible in comparison until we consider the extraordinary velocity of the acceleration wave that is set in motion within the brain substance by solid impact. In this respect the blast wave and the acceleration wave are similar. Apparently the nervous system possesses a better natural armor against the blast wave than either the chest or the viscera.

The severe intra-abdominal, as well as pulmonary trauma, from immersion explosion has been impressed upon us recently, as Dr. Palma has told you, and here again the effect on the nervous system is in even less comparable degree than in atmospheric blast. The survivors had their heads above the surface when the underwater detonation occured. None of these men showed definite neurological signs but there were instances of pleocytosis in the cerebro-spinal fluid, and in every case this finding was associated with typical pulmonary pathology. Subarachnoid hemorrhage was presumably a result of concussion on the leptomeninges of the spinal cord. There were also examples of disturbed cortical function in some of these patients which we are at a loss to explain adequately. It is further evidence of the total effect of blast injury.

There is one other subject I should like to call to your attention. War experience with sulfonamide therapy has enabled considerable alteration in the treatment of compound cranio-cerebral injuries. In general, patients with such complications, probably excepting fractures through the paranasal sinuses, can safely wait several days for major surgery if sulfanilamide is used locally after superficial debridement, and sulfadiazine internally. The hazard of delay to counteract shock is less, while the time allowance is greater for transportation to a locality where proper operative facilities can be provided.

These remarks on head injuries of the present war are meant to supplement Dr. Cloward's discourse and are offered because of the timely possibilities they may suggest for preventive measures as well as for clinical management.

Orthopedic Wounds

J. D. MACPHERSON, LIEUTENANT, M.C., U.S.N.R.*

The tempo and range in field of modern warfare requires many changes in treatment of orthopedic conditions which were not necessary when sudden evacuation of casualties was not an important factor.

In the event of an air raid we must be able to evacuate our hospitals in a few minutes. If the patient is to be transferred to the mainland he must not be in cumbersome apparatus which will cause difficulty in care and transportation, or prevent quick removal from the ship, should the occasion arise. For these reasons we have almost entirely discarded traction as a method of treatment and substituted open operation with plating, or reduction of the fracture with two or more pins incorporated in the cast.

Early during the raid of December 7 our orthopedic staff contacted the x-ray department and arranged for rapid development and drying of films. As a result of their excellent cooperation, these were soon punched, marked with baggage tags, and tied to the patients' beds. Charts, and all information pertaining to a patient, were also attached to the bed, so that hurried notes could be made. When the patient had been given attention, a large "X" was marked on his bed tag in red pencil. This served to avoid much confusion and unnecessary questioning of the patient.

As we had previously agreed, we used no antiseptic solutions other than soap and water about and in the wounds. We did find it necessary to use a solvent for oil in some cases, since many of the men were covered with thick fuel oil. For these cases we used ether, but we have since been informed of a simpler method. It appears that ordinary mineral oil will cut the heavy coating, and, after its application, soap and water may be used. Debridement was performed under local or spinal anesthesia, taking care to leave no overhanging edges or pockets. Following this, the wounds were generously "salted" with sulfanilamide and a non-occlusive dressing of vaseline gauze was applied. We closed very few of our wounds. Those that were sutured were usually of the incised type rather than the extensively lacerated variety which are produced by high-explosive shell-fragments.

These shell-fragments are extremely hot, and at the first dressing, three or four days later, will be found to have produced a grayish slough which may be easily removed to reveal a red healthy-looking base. The wound may then be "salted" again, and thereafter be dressed as infrequently as possible.

Extensive lacerated wounds of the extremities and compound fractures were placed in plaster casts as soon as possible, since plaster of paris has decided advantages over any other treatment in these cases.

Immobilization in plaster produces comfort by elimination of reflex muscle spasm, and gives an evenly distributed pressure over the wound. It lessens swelling and edema, and since infection spreads through the lymphatics, it should tend to confine the reaction to the wound itself. For this reason we favor the unpadded cast, as advocated by Bohler, and rather than cut a window for dressings we would apply a new cast. Cutting a window allows the tissues about the wound to herniate through the cast resulting in edema and spread of infection. If one must cut a window, let him use padded casts.

Those fractures which we could reduce manually were reduced immediately after debridement, and casted. Those which were more complicated were reduced later, using pins or wire. We found it necessary in many instances, against our better judgment, to use a pin at one end of a bone and a wire at the other. The wire alone will bend in the cast and allow the fracture to slip unless it can be held taut. However, we were unable to transfer our Kirschner bows along with our patients, due to a scanty supply, and we therefore recommend that a good number of Steinman pins be kept on hand.

It is my opinion that some of these compound fractures could safely be plated, since there is probably no more danger of the screw-holes' introducing infection than the open marrow cavities exposed in the wound. I believe the new Gilfillan plate is well suited to this type of treatment. This plate is of stainless steel and has slotted, instead of round, holes, which will allow impacting of a fracture after it is applied and before the screws are tightened. It is flanged so that a minimum amount of metal comes in contact with the bone. The screws are "self-tapping", and, unlike most bone screws, can be loosened after insertion and re-

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tightened without stripping the threads. Two plates are applied to the femur, one on top of the other, thus giving great strength. The cast can then consist of an abdominal band with a lateral splint as far as the knee. This would be of great advantage in transportation.

On a recent trip to the mainland I saw these plates used on the tibia in simple fractures. The patient may bear weight on the leg, with the aid of crutches, but no cast is used for fixation other than a moulded splint which is removed as soon as the wound is healed.

The hanging cast for fractures of the humerus has recently become popular. I believe it to be practical for our purposes, since it is easily applied and allows the patient to be up and about. However, it is an ambulatory type of treatment, and if the patient is recumbent it loses its value. It produces traction by its own weight, and control of the fragments for antero-posterior position is accomplished by altering the length of the sling. Pads placed either at the elbow or in the axilla are used to correct medial or lateral bowing.

If a shoulder spica is used it should not be too widely abducted, and the arm should be carried somewhat anteriorly to allow the man to get about and through narrow passageways. Fractures of the forearm are more easily handled, from the transportation standpoint, but end results are often not as good. I have recently acquired an inexpensive traction device which I believe will enable us to perform better reductions. It consists of a metal modification of the old wicker finger traps, connected by pulleys to a metal bar. With the elbow flexed and stabilized, and the fracture point anesthetised, 15 lbs. of pull is exerted for a period of 15 minutes. Most fractures of the lower forearm will reduce themselves in this manner.

For fractures of the femur, we believe the single leg spica to be most useful, since a double spica causes considerable difficulty in transportation. If the fracture be in the middle or upper third, it is well to run the spica to the nipple line to insure immobilization.

An indelible pencil should be used to draw on the wet casts pictures of fragments and wounds, and to give pertinent information. In some cases, we attempted to inform the receiving hospital on the mainland of what we had aimed to do in the treatment of the case. As an example, I have in mind the interesting case of a young officer who sustained a severe wound and a badly compounded fracture of the left thigh and femur. A large section of the left femur was missing upon arrival at the hospital, probably carried away by the flying fragments which injured him. The soft tissue wounds of the thigh were treated by the surgical service. The patient was then seen by us on orthopedic consultation. We felt that in this type of case, where a large section of the bone was missing, there might be enough of the periosteum left for bone regeneration. Accordingly a Steinman pin was inserted in the upper end of the tibia, the leg was "pulled down to length", and a one leg plaster spica applied for transportation back to the mainland. This information was transcribed on the cast.

I feel that we have gained invaluable experience from our treatment of war wounds. Winnett Orr, whom we must thank for our method of casting compound fractures, still maintains that the principle of physiological rest in plaster is responsible for the good results obtained, rather than the use of sulfanilamide in wounds. In view of the fact that the wounds we received were fresh and were not usually sustained in a grossly contaminated area, and since shell fragments are usually so hot that they have a cauterizing effect, I do not believe we can definitely say from our experience that at last we have reached a chemical cure.

I shall continue to use sulfanilamide, since I feel sure that it is of great value, but I shall not forget the principles of surgical drainage and physiological rest. Since the battle of Midway I am more convinced than ever that these cases must be thoroughly debrided. You cannot count on the sulfa drugs alone.

DISCUSSION

LT. COL. ROBERT C. ROBERTSON: It was my good fortune to serve for a short time on the orthopedic service of a mainland hospital to which our Army casualties of December 7 were evacuated from this department. Practically all of these cases had been initially treated in accordance with principles set forth by Dr. Macpherson. Our entire staff was highly pleased with the general and local condition of these men upon arrival. This condition we attributed to the skillful care received prior to and during evacuation.

Our observations on the orthopedic group were as follows. Wounds in many cases were open. Many of these were definitely infected. This infection was of low grade type without systemic symptoms, and, with very few exceptions, was controlled by the use of Bipp dressings, or sulfanilamide powder covered with vaseline gauze. Split skin or pinch grafts were successfully used to hasten healing as soon as practical, the local criterion being clinical appearance of the granulating surface rather than bacteriologic methods.

Major amputation wounds were open on arrival. Soft tissue flaps for the most part were adequate. Fixed skin stump traction attached to wire loops incorporated into supporting casts were used during transportation. This was of great value in preserving flap length and greatly facilitated plastic closure of the stump wound. The advantage of this procedure for evacuation might be further increased by the use of an interposed elastic device to compensate for the loosening of the traction which occurred in several instances. Plastic closures were performed early by excising en masse all granulation tissue, shortening the bone at a slightly higher level, shaping and loosely suturing the flaps. Stump traction was employed post-operatively. Drains were removed early. In only one case did low grade infection follow this procedure. In this case secondary hemorrhage was also troublesome. Nearly all of the amputees now have their prostheses and have either been given C.D.D.'s or returned to duty. These amputees with wounds open, and adequate soft tissue flaps, were among our most gratifying cases.

Fractures were x-rayed on arrival, and if apposition and alignment were satisfactory, the supporting cast was not initially changed. No case of true infectious ostomyelitis was encountered in these cases, although in several extensively comminuted fractures, spicules and fragment of bone were subsequently picked from the wound. Wire encirclage was encountered in three extensively comminuted fractures. Cases with extensive loss of bone substance have not yet been grafted, although this is contemplated at an early date.

Nerve and tendon injuries were well supported with parts in position of election prior to evacuation. Plastics and nerve repairs are now being done on some of these cases.

A recent personal communication from the present chief of the orthopedic section permits the above statements relating to present status of these cases. His letter reads in part, "The general results were good. I am sure everyone will have to agree that these good results can be attributed primarily to two things, namely; the prompt and skillful treatment received there, and the use of the sulfonamides. All of the cases . . . were given thirty day furloughs and many have already returned to duty."

Experience within the American Army to date, as well as reports from our allies, indicates that orthopedic treatment of war wounds should observe the following principles:

1. Mechanical cleansing of the wound at the earliest possible moment.
2. Loose, wide-open packing of the wound with infrequent dressings.
3. External continuous fixation of fractures by a method which will permit early mobility of the patient, and simplify evacuation.
4. Adequate soft tissue flaps in amputation stumps.
5. Skin grafting at an early date.
6. Delayed nerve and tendon repair in extensive wounds.
7. Sulfonamide therapy.

The detailed methods whereby these principles may be best applied within the theater of operations will largely be governed by time, distance, and personnel. Despite the advantages claimed for any one method, our corner-stones must continue to remain prompt treatment and skillful treatment adapted to the needs of the individual case.

Burns: A Treatment Plan for Large Numbers

PAUL C. SPANGLER, LIEUTENANT COMMANDER, M.C., U.S.N.R.*

The treatment of the occasional burn case offers no real problem. All of you here are familiar with the several different methods of burn treatment. All of these methods have their merits and the intelligent use of any of them will produce good results. Certain situations may best be met by constant wet dressings. The compression dressing, with or without local medication, has the advantage of physiological rest and will be found useful in some cases. Immersion treatment is still valuable, especially in children. Then we come to the various crust formers, such as tannic acid, with or without silver nitrate; the triple dye, composed of methylrosaniline, brilliant green, and acriflavine, having specific selective antiseptic actions against the common bacteria encountered; and finally the sulfadiazine in triethanolamine. Any one, or a combination of these methods, may be selected for the occasional case with good results.

A sudden influx of a large number of burn casualties, such as we experienced on December 7, offers an entirely different problem. In such a situation we must have some standardized plan of treatment readily applicable to a large number of casualties, which (1) may be quickly applied, (2) is known to be a satisfactory means of treatment, and (3) can be administered under the direction of the doctor, often by less skilled persons.

At the Naval Hospital at Pearl Harbor on December 7 we treated several hundred burns. Many different methods of treatment were used. We had an excellent chance to observe the results of these different methods of treatment and their applicability to mass treatment. Following this experience a burn committee, of which I was a member, was appointed to evaluate our results, to adopt a standardized procedure adaptable to large number of casualties, and to make provisions for equipment supplies and instructions. We have adapted the report of this committee to our use at Mobile Base Hospital No. 2, and I would like to present this standardized procedure to you at this time.

EXTENSIVE AREAS—SERIOUS

Treat patient first.

For pain and anxiety, give morphine grains ½ and repeat as necessary. Keep accurate record of all medications. An important feature of many of our cases was the extreme anxiety. We believe this is as important an indication for sedatives as is pain.

Put patient to bed under a heat cradle. Elevate the foot of the bed. Avoid chilling. These are just routine measures to combat shock.

Give adequate fluids by all routes. Except in extreme cases, the parenteral fluids should not exceed the volume of plasma given. Caution must be observed in the administration of saline solution as an excess may promote further loss of fluid into tissues.

Give plasma in adequate amounts to control shock and hemoconcentration. Hemoglobin determinations are more practical than hematocrit in the evaluation of the hemoconcentration in a large series of cases. Ephedrine or cortical adrenal extract are valuable adjuncts in the control of shock.

Diet should contain abundant proteins, especially albumin and gelatin.

Continually watch for and treat shock.

Later, after shock is controlled, treat burned areas.

First and second degree burns:

Expose minimal area of body at one time.

Cleanse burned areas, using soap and water. Liquid petrolatum for oil and grease, followed with soap and water. Detergents such as sodium lauryl sulphonate are valuable in cleaning these surfaces. Thoroughly debride all burned areas, removing all loose skin and vesicles. Dry gauze is quite efficient in removing this loosened skin. Narcosis and anesthesia are used if indicated. Usually morphine in liberal amounts is adequate.

Freshly prepared 10 per cent tannic acid solution is painted or sprayed on burned areas. This is followed by freshly prepared 10 per cent silver nitrate, applied with cotton swabs, using a fresh swab each time. It is well to allow a ten to fifteen minute interval between tannic acid and silver nitrate applications.

No dressings. Warm air under cradle. Maximum temperature 85 F.

For hands, feet, face and genitals use 1 per cent sulfanilamide in vaseline. Cover hands and feet with vaseline gauze dressings. Do not change unless infection develops. This should be a bulky firm dressing to provide physiological rest.

Dust sulfanilamide powder where crust cracks.

As crust loosens, cut it away, being careful to cause no trauma.

Oiled paper on the bed will protect the linen and prevent bed clothing sticking to the burn.

Watch for and treat any infection which develops. Cut away the crust and apply sulfanilamide powder.

Record all medications fully.

Third degree burns:

Debride lesions of all charred dead tissue.

Apply sulfanilamide powder.

Dress and treat as an infected wound.

Tetanus toxoid or antitoxin should be given to all serious cases as indicated.

SMALL AREAS—LESS THAN 20 PER CENT

Shock is not a factor. You may proceed with local treatment almost immediately, as outlined for severe burns. Tetanus toxoid or antitoxin should be given to all serious cases, as indicated.

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Laboratory work is important on serious cases; red blood count, hemoglobin, hematocrit and serum albumin all give valuable information regarding hemoconcentration and the degree of shock. From a practical point of view, repeated hemoglobin determinations will probably give sufficient information as to the progress and indications for treatment. Serum chloride will be a guide to the indication for administration of sodium chloride. Daily urinalysis and twenty-four hour urinary output are important to detect early evidence of kidney damage and indication for parenteral fluids. The urinary output should be kept over 1000 cc. daily.

First Aid

I cannot leave this subject without saying a few words about the first aid treatment for burns. First and foremost is the universal axiom of first aid, "Do no harm." Smearing burns with the first grease handy does harm and must be condemned. Use no grease or ointments in first aid. Tannic acid jelly, with or without sulfanilamide, is satisfactory. Wet dressings, such as a towel moistened with soda bicarbonate solution, normal saline, or even water, is satisfactory. Adequate morphine should be given if available. If facilities for the administration of plasma are available, it might be well to give this medication to seriously burned cases before the patient is sent to the hospital for the ultimate treatment of his burns.

Conclusion

We are not maintaining that the method of treatment here outlined is the only, or necessarily the best, type of burn therapy. We are convinced that, based on our experience of treating several hundred cases on December 7, this is the most satisfactory system of handling a large group of burns. The Bureau of Medicine and Surgery of the Navy in April of this year issued a directive recommending this form of treatment.

Discussion

Dr. F. J. Halford: Dr. Spangler has, in a very thorough manner, covered the principles concerning the treatment of burns. I wish to make a plea, however, that each doctor acquaint himself with the absolute necessity of converting a burn case from a dirty and infected wound into a clean wound. This one factor alone is agreed upon as fundamental in all methods of treatment of burns, and it is perhaps the most frequently overlooked, despite the great volume of writing on the subject.

The burned patient may die from one of three causes: secondary shock, which usually ensues within twenty-four to forty-eight hours; if the victim survives this period, he then may go out from kidney destruction and liver damage; and if still surviving, he may die of secondary infection.

The dread of secondary infection in a burn wound cannot be overemphasized. I do not feel that Dr. Spangler's cases were adequately described, in that "flash" burns produce death usually in such a short time as to give no opportunity for secondary infection to set in.

In any surgical condition where there is so much confusion concerning the treatment, one readily recognizes that certain principles should be established, and the end results critically compared.

We are all agreed that burn cases must be cleansed and debrided no matter what other form of local treatment is given.

We are all agreed that plasma must be given in sufficient quantities to enable the patient to withstand the onslaught of secondary shock and plasma loss.

I wish to present at this time a modified form of "Triethyl-diazine" with methyl-cellulose as its base, developed by the Lederle Company. This not only allows for rapid drying and formation of an eschar, it also supplies a severely burned patient with sufficient sulfadiazine by direct absorption to take care of the first twenty-four to forty-eight hours. It relieves pain, gives a transparent eschar and is easily removed. There are several drawbacks, however. It must be sprayed on every two or three hours and you may get a toxic absorption of sulfadiazine, and it does not work if you do not cleanse the wound.

It should be remembered that sulfadiazine may be given either in tablet form or as the sodium salt intravenously. These forms of the drug are available in all our civilian hospitals. For local treatment, where there is such a shortage of valuable sulfadiazine solution, I advise the use of three other methods:

(1) Sterile vaseline gauze, applied to the *CLEAN WOUND* (which you have converted from a dirty wound) and bound tightly with roller dressings to act as a pressure bandage. These are left alone for six to ten days. They give excellent results.

(2) Five per cent tannic acid with ten per cent $AgNO_3$ solution swabbed on the *CLEAN WOUND* until a satisfactory eschar has formed. Under no circumstances should any coagulant be used on the fingers or toes because of the gangrene frequently produced by constriction of these parts. Likewise one should never use this method on or about the face.

(3) Triple dye, consisting of two per cent gentian violet, one per cent brilliant green, and one-tenth per cent acriflavine, swabbed on the *CLEAN WOUND* until a dried and pliable eschar has formed.

As far as the general treatment of burns is concerned, you must give a generous supply of oxygen to take care of the hypoxia and anoxia. We civilians are handicapped here, since we do not have an adequate supply of oxygen.

We should have more generous use of plasma: not 1,000 or 2,000, but as high as 6,000 cc., over a two to four-day period, because we are not going to have time for the falling drop or hematocrit determinations.

It should be remembered that fresh plasma is superior to dried or frozen plasma in that it has not been robbed of many of its essential elements.

Dr. Bronson: I was impressed by the suggestion that we sterilize our burn cases. This is all very well until you have a hundred of them in the field. On December 7 we put on lots of tannic acid but I did not like the tannic acid treatment. We used a considerable amount of sulfa drugs in mineral oil which at least was soothing to the patient and I think we had just as good results as by any other treatment I have seen. The sulfa drugs in oil did not crack like tannic acid and did not give a thick coat and it seems there were fewer infections.

Blast Injury of the Lungs

With Comment on Immersion Blast Injury

Joseph Palma, lieutenant commander., m.c.-v(s), u.s.n.r.*

Blast injury, caused by the detonation of high explosive, is of increasing importance in both military and civilian medicine because of the development of long-range artillery operations (aerial warfare) of World War II. It is of particular importance to civilian communities, vulnerable as they are to the indiscriminate bombing of large concentrations of people in confined spaces. Prompt recognition of this condition so that proper, early and effective treatment can be instituted is the first responsibility of all personnel charged with the care of war casualties. In these cases, more than with the other types of war casualties under discussion this afternoon, the treatment of shock is the paramount duty of the medical or first aid attendant. Oxygen therapy in particular may be life saving in blast injury.

Etiology

Blast injury is caused by the positive pressure wave created by the detonation of a high explosive. It is a compression injury which occurs in a fraction of a second, in contradistinction to similar compression injuries observed in civilian life usually occurring over a much longer period of time. The wide varation in the severity of symptoms, course of illness and possibly the complications of blast injury can be explained by (1) proximity to the blast, especially if in a confined space; (2) the fact that the positive pressure component of the longitudinal and excessively intense sound wave produced may be as short as .006 second and can, therefore, strike the individual at any one of many phases of a 3.3 second respiratory cycle during which the unequal enlargement of the thoracic box entails unequal expansion of the lungs, and (3) the youth, size and nutritional state of the individual.

Experimental evidence is offered by the reports of Hooker[1] and Zuckerman[2] as proof that the positive component of the pressure wave produced by the blast acts externally on the thorax to cause the injury rather than (1) the lowering of alveolar pressure by the negative (suction) component of the wave, acting through the respiratory passages, with consequent rupture of the alveolar capillaries, or (2) distention of the lungs with air. Zuckerman exposed mice, rats, guinea pigs, rabbits, cats, monkeys and pigeons to charges of 70 pounds of high explosives and to explosion of hydrogen and oxygen in balloons and found that these animals were never killed at distances farther than 18 feet, and that none were ever hurt at distances greater than 50 feet from the explosion. Almost all the animals within 13 to 18 feet were killed. At these distances the positive component of the blast wave varied between 126 and 63 pounds per square inch. However, animals whose bodies were protected with a thick layer of rubber suffered little or no damage. In no animal was there any external sign of injury.

The excellent monograph of O'Reilly and Gloyne[3], describing a series of 17 cases of blast injuries to the lung in which the "circumstances of the injury comply with the criteria set up by Zuckerman (1940) in his experimental work as nearly as is likely to be in human cases," and a series of 20 cases described elsewhere[4] by W. M. Enright and myself, wherein we believe the circumstances likewise comply with these criteria, comprise the material from which these remarks are prepared.

Pathology

The principal lesions produced by blast are found chiefly in the lungs, central nervous system and abdomen. In the lungs, they consist of hemorrhage, either multiple diffuse capillary bleeding into the alveolar spaces or massive bleeding at the root of the lungs or collected in the costophrenic sinuses with associated rupture of the elastic tissue of the alveolar walls. The lesions of the lung frequently follow the lines of the ribs.

The central nervous system suffers from multiple subarachnoid hemorrhages with possibly an associated molecular concussion from the velocity factor. This subarachnoid hemorrhage is produced, most likely, by the tremendous pressure developed in the venous system from the sudden compression of the thoracic cage.

The abdomen manifests mainly a considerable degree of muscular rigidity resulting either from intramuscular or intravisceral hemorrhage or, more likely, from irritation of the intercostal nerves caused by hemorrhage into their sheaths.

Clinical Features

The clinical features of blast injury as presented in the 20 cases observed at the U.S. Naval Hospital at Pearl Harbor after the attack of December 7,

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1941*, were so similar to those described by British authors that we felt justified in our diagnosis even though we had no postmortem proof. In different combinations and in varying degrees of severity they manifested shock, respiratory difficulty, chest pain, cough, cyanosis and restlessness. These men had been in the vicinity of high explosive detonations, often in a confined space; they presented no external evidence of injury; and they were admitted to the hospital within a few hours after injury.

The observer is impressed with the degree of shock, out of proportion to the apparent injury. Pallor, cyanosis, and rapidity and poor volume of the pulse are all striking. Dyspnea is a constant feature; the respiratory rate is rapid, the excursions shallow, and inspiration particularly difficult. Pain in the chest further complicates the respiratory effort, and in our cases it was more often lateral than central. Cough, which may not develop immediately, is spasmodic, frequently intractable and productive of a frothy, blood-tinged sputum. Cyanosis, of course, varies with the severity of the injury. Restlessness is a constant feature and may be extreme. This symptom should not be interpreted as due to psychic trauma but rather as evidence of the irritative lesions (hemorrhage or concussion or both) of the central nervous system.

The physical findings are chiefly in the chest and vary with the severity of the condition. Respiratory excursions are reduced, but generally equal on both sides; diminished air intake is a striking feature. The percussion note may be resonant in the early stages with localized areas of dulness later if complications occur. Palpation gives no additional information. On auscultation, the breath sounds are faint, especially at the bases, and coarse or sibilant rales over the whole of the lung fields are common in all cases.

Roentgenograms reveal characteristic poorly demarcated areas of increased density (mottling) scattered throughout both lung fields, resembling somewhat a patchy pneumonic consolidation.

Uncomplicated cases recover in four to fourteen days but secondary infections are not uncommon, and pneumonia is a frequent complication. Four of our series developed bronchopneumonia with typical signs and symptoms added to the symptoms just described. Response of these bronchopneumonias to sulfadiazine therapy was dramatic and satisfactory. Dosage should be sufficient to produce and maintain a blood concentration of at least 15 mgm. per hundred cubic centimeters. This is easily accomplished by giving the calculated daily maintenance dose initially and following up with the usual 4 hour schedule.

*13 of these were classified as mild and discharged to duty symptom free in 7 days; 3 as moderate, returning to duty in 14 days; and 4 as severe and evacuated to the mainland after two months' hospitalization.

TREATMENT

The treatment of blast injuries is predicated on their early recognition and prompt application of strict bed rest. Then shock should be treated by the usual methods, using plasma transfusions, if needed. Large amounts of fluid by mouth are well tolerated. Morphine, grs. ¼ or ⅛, hypodermically, frequently is the drug of choice to control restlessness and pain. Codeine, gr. ½, by mouth, may be needed in addition to relieve the spasmodic cough. Oxygen is life-saving and should be administered continuously, in the early stages at least, by tent or B.L.B. mask. The rate of flow should be faster than usually employed: 8 to 12 liters per minute. Since these patients may continue to bleed and develop secondary infections easily, they should be moved about as little as possible and bed rest should be prolonged and sulfa drug therapy employed.

Three interesting cases of blast injury — one mild, one moderate and one severe—are here reported:

CASE REPORTS

Case 1. This man was reading in his bunk, partially prone, with the left side on the mattress, the right shoulder elevated and the right leg resting against the bulkhead, when he was exposed to severe blast causing the vivid impression of being bounced about between the bulkheads. Then blackout for four hours, until he regained consciousness. Twenty-four hours later he complained of severe pain in the right hip which was increased on motion of the lower right extremity. There was associated shortness of breath and some slight difficulty in breathing. There was no cough or hemoptysis as far as he could remember. Inspection revealed fullness of the neck extending down over the clavicles anteriorly and extending at that level around to the back. The characteristic crepitation of subcutaneous air was noted on palpation over this area. The man was comfortable and breathing easily, and there was no cough or cyanosis. On percussion there was slight dulness over the right base with a few coarse rales heard on auscultation. There were no breath or voice changes but diminished air intake was noted laterally.

The neurological examination was negative except for a fine nystagmus to the left and definite reflex changes. Tendon reflexes were active in the upper extremities and diminished in the lower, with bilateral Babinski signs, more striking on the right side. These signs were interpreted as evidence of pyramidal tract damage from blast, subcortical in location.

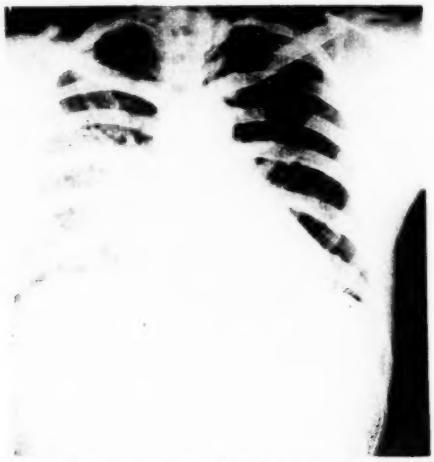

Fig. 1. Typical blast injury effect, involving chiefly the lower 2/3 of the right lung (case 1).

Roentgenograms of the pelvis showed injury to the acetabulum of the posterior and inferior hip, apparently the result of the direct impact of the vibrating bulkhead. The chest showed evidence of typical blast injury, involving especially the lower two-thirds of the right lung with moderate involvement of the left lung and emphysematous areas extending well up into the neck muscles (fig. 1). These findings are easily explained if one remembers the position of the patient when exposed to blast.

No treatment other than bed rest was needed. One week later the patient was asymptomatic. Recovery is to be expected with possibly some reduction in vital capacity. Ten days after injury the subcutaneous air was almost completely absorbed and a roentgenogram of the chest showed, for the first time, beginning resolution.

Case 2. This man was in the immediate vicinity of a high explosive blast and he remembered inhaling an acrid-smelling smoke for a moment or two afterward. During the next twelve hours there were no symptoms except slight nausea. Then he noted some pain in the chest and shortness of breath on slight exertion which increased in severity over an eight hour period.

At this period, twenty hours after the injury, he was admitted to the hospital in a state of moderate shock, extremely restless, with shallow, rapid and painful respirations. He was moderately cyanotic and there was some cough. The temperature was 100.6 F., pulse rate 110, and respirations 38. Examination of the chest revealed only a few scattered rales. There was no external evidence of injury. Roentgenogram of the lungs showed many areas of increased density scattered throughout both lung fields. These varied in size but were relatively small and poorly demarcated. There was some confluency of these shadows, particularly in the region of the right middle lobe. The pulmonary findings were reported to be compatible with the after-results of a blast injury (multiple pulmonary hemorrhage) (fig. 2).

The patient was immediately placed in an oxygen tent; fluids were given freely, and morphine sulfate, gr. ½, was given hypodermically as needed for the relief of pain and restlessness. The next day he was worse: temperature was normal, the pulse was 100 and respirations had increased to 50. On the second and third days there was little change in his condition, clinically or radiographically. Improvement began on the fourth day and continued rapidly. He raised a quantity of muco-purulent frothy sputum. On the fifth day he was removed from the oxygen tent, although the respiratory rate was 32 per minute. Clinically he was much improved. The x-ray, however, showed little change. (fig. 3).

Case 3. This patient developed progressive respiratory difficulty after exposure to blast and smoke. He was in moderate shock, cyanosed, coughing and restless, and his chest excursion was very limited. He was coughing up considerable blood-tinged sputum. His chest was hyper-resonant and there were disseminated rales, crepitant to coarse. His temperature soon rose to 102 F. and oxygen was necessary to control respiratory distress. The roentgenogram revealed a light ground-glass ap-

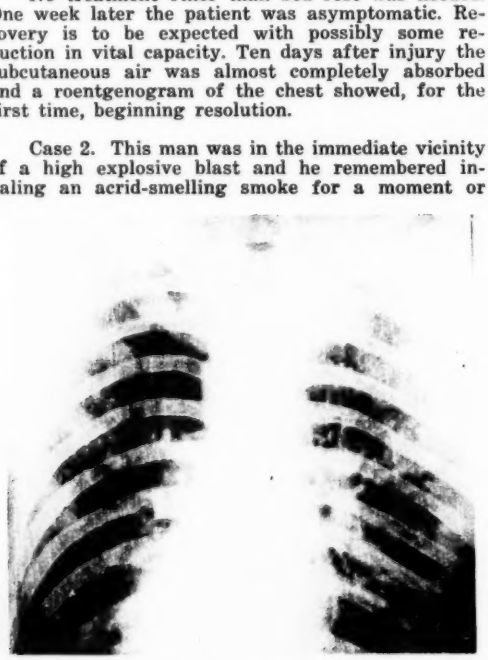

Fig. 2. Multiple areas of increased density scattered throughout both lung fields (case 2).

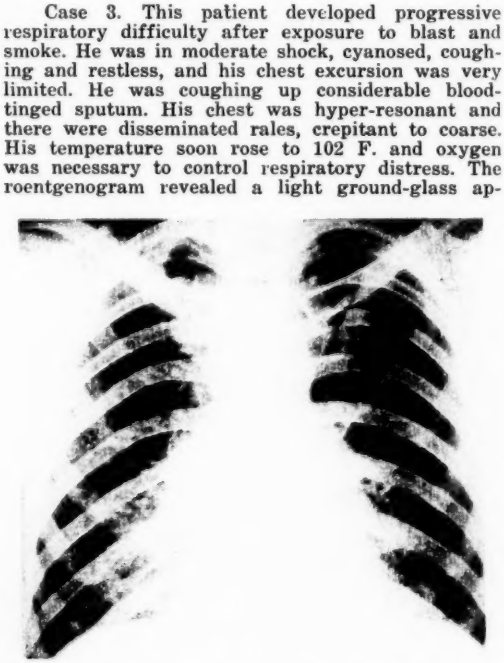

Fig. 3. Same chest as fig. 2, 5 days later, showing some clearing.

Fig. 4. Intense bilateral mottling of lung fields (case 3).

Fig. 5. Same chest as fig. 4, 5 days later.

pearance throughout both lung fields which was reported as a "bronchiolitis."

He was started on sulfadiazine. Morphine sulfate, gr. ¼, was given frequently hypodermically.

12-14-41. The patient was in acute respiratory distress with shallow rapid respirations not well controlled even with oxygen. He had numerous, severe coughing spells which responded fairly well to codeine. He was raising a large amount of grayish frothy sputum which on occasions was bloody. A blood count showed 4,150,000 r.b.c. and 8,750 w.b.c of which 76 per cent were polymorphonuclear neutrophiles.

12-28-41. All the aforementioned signs and symptoms persisted. At this time the white blood count was 12,400, of which 70 per cent were neutrophiles. The sulfadiazine level was 9.3 mgm. Urinalysis was negative, sputum was negative for acid fast bacilli.

1-1-42. The patient was still acutely ill with signs and symptoms still present. The sulfadiazine level was 14.4 mgm. X-ray showed intense bilateral mottling of the lung fields (fig. 4).

1-4-42. The patient was breathing much more freely and his temperature had become normal. Both objective and subjective signs of acute pneumonic pathology had diminished in spite of x-ray evidence which showed no diminution of the lung process (fig. 5). Sulfadiazine was discontinued.

1-10-42. The patient continued to improve and was up in a wheel chair for periods of one hour.

1-21-42. Six weeks after injury a roentgenogram of the chest showed very little change, although the patient was clinically improving daily.

IMMERSION BLAST

Blast injury occurring in the water has been given the name of "immersion blast" by Surgeon Commander Rex Williams, R.N. Several cases of this type of injury have recently been under observation at the Pearl Harbor Naval Hospital. The pathology, unlike that of atmospheric blast, is chiefly in the abdomen.

As was stated earlier, blast wave is an excessively intense longitudinal sound wave, and, in water, sound waves travel four times as fast as in the air. It seems reasonable to assume, therefore, that the critical distance from the origin of the blast is four times as great in the water as on land. It is not clear at this time whether the abdominal injuries are the result of sudden compression of the abdomen or of the transmission of pressure through the pelvic floor and anus, comparable to compressed-air hose injuries seen in civilian practice. It is probably a combination of both factors.

A full report of the type of lesion produced in the abdomen will be made at a later date when all the material at hand has been completely studied, but this much can be stated now: the small bowel is apparently more vulnerable to "blast" than the large intestine. The terminal ileum was most frequently involved, then the cecum posterior wall of the ascending colon. Grossly the lesion produced was a transverse submucosal tear in one or several locations, in some instances extending down to the subserosa. The intestine also exhibited patches of hemorrhage covered by a fibrinous exudate and the omentum. Perforations, when they occurred, were punched-out in appearance and were possibly the result of (1) immediate rupture from compression, (2) interference with the blood and nerve supply, or (3) the increasing pressure and distention of ileus. Rupture of the liver and spleen did not occur.

The presenting signs and symptoms were those of moderately severe shock. This was treated by the

accepted methods: plasma and other fluids intravenously, morphine, heat, etc., with decompression of the abdomen by Wangensteen suction or Miller-Abbot tube. Sulfadiazine intravenously, in those cases where its use was indicated, was of the greatest value. Of the cases admitted to the hospital 75 per cent recovered. The only surgical procedure employed was drainage of a localized abscess in one patient. However, in cases of immersion blast seen early, that is, within the first 24 hours, the surgeon would be justified in opening the abdomen with the expectation of finding the majority of the lesions in the terminal ileum, cecum, and ascending colon.

SUMMARY

1. Blast injury (concussion) of the lungs is of increasing importance, especially to civilian communities.

2. The clinical picture presented by this injury is typical and should be recognized early so that proper therapy can be instituted.

3. In all war casualties, regardless of the type of injury produced, if there has been exposure to the detonation of high explosive, the integrity of the chest should be ascertained by x-ray examination because general anesthesia is contra-indicated when there is blast injury of the lungs.

4. Dr. Hamlin, who will discuss the neurological features of some of these cases, agrees with me that blast injury should be regarded as a "total injury" of a "total war." The outstanding signs and symptoms may be predominantly either in the chest or abdomen depending on the circumstance of their production; i.e., atmospheric or immersion blast. The vascular system is the most vulnerable of the tissues to the effects of blast. Hemorrhage from rupture of the capillaries, either multiple punctate or massive, is the lesion common to all. The less obvious but equally important secondary effects of the injury in the autonomic and central nervous systems add to the complexity of the injury and compel further and long continued observation of the patient.

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DISCUSSION

DR. R. N. PERLSTEIN: The paper just presented is a very complete and careful clinical report on a condition which, while not new, has received more emphasis and elucidation than almost any other in the present war. The author is to be congratulated on a very excellent presentation and his summary of the literature leaves very little to be added.

From the standpoint of the civilian physician who may be called upon to treat such cases, it is well to remember that many, if not most, such cases will not show external lesions of any kind and that a history of exposure within fifty feet of an exploding bomb may not be obtainable. The signs of injury to look for, then, are very important. The patient as a rule complains of tightness in the chest and difficulty in drawing breath. His breathing may be rapid and shallow, or slow and labored. He may have a rapid pulse and low blood pressure. Both of these symptoms may be aggravated by the slightest exertion. There may be hemotysis or cyanosis and there may be thin, frothy sputum. Since not all of these patients need to be x-rayed, it is valuable to remember that a good lead on exposure to severe blast is furnished by examination of the ears. A recently ruptured tympanic membrane usually indicates exposure in the near vicinity of blasts and necessitates a chest x-ray to rule out blast injury to the lungs.

In the most recent of three important contributions to this subject by Zuckermann, a number of interesting points are made as a result of carefully controlled animal experimentation. First, that the death or survival of the patient exposed to blast injury is more closely connected with the amount of pulmonary damage done than with damage to any other tissue. Second, that the exposed person or animal suffers severe bruising of not only the lung but frequently the abdominal organs too, as well as retrobulbar hemorrhage and rupture of the ear drums. Third, that sudden death from blast is usually associated with immediate arrest of circulation and does not depend upon ventricular fibrillation. Fourth, that fall in blood pressure is caused by reduction in the pulmonary vascular bed caused by the trauma of the blast and that any procedure that increases the venous return to the heart is liable to cause further drop in the systemic blood pressure. This is true of compression of the abdomen, exertion, general anesthesia and even blood transfusion so that the latter two are contraindicated in severe blast injury. Elevation of the inspiratory rate is explained on the grounds of hemorrhage into the lung and patchy atelectasis. Lastly, it is interesting to note that animals exposed in the near vicinity of high explosives with the trunk and thorax encased in a steel cylinder suffered no pulmonary injury, and also, in the majority of instances where there was no skull fracture or cervical fracture, suffered no intracranial injury.

In human subjects, therefore, one must not expect concussive phenomena but must look for clinical signs and symptoms already mentioned which lead to the suspicion of pulmonary and abdominal organ damage. Treatment has been well outlined in Dr. Palma's paper and the only caution it is at all necessary to make is one against the too liberal use of morphine, especially where large areas of lung damage are thought to exist.

DR. LOVE: What difference do the concentration of the sulfa drugs make? I wonder how many men in actual practice or under war conditions are fooling with blood concentrations?

DR. PALMA: I can answer that if you will take your hand off your gun!

It is an accepted fact that there are optimum concentrations in the blood for the different sulfa drugs, but if you have a condition where you are not getting a response and the patient otherwise will die, you had better give him a bigger level. You can give up to 50 or 60 per cent.

DR. LOVE: In how many patients do you change the dosage?

DR. PALMA: There is so much variation in an individual's absorption you cannot follow it without the laboratory. The dosage is many times changed for a given patient.

DR. HAMRE: Do you consider venesection for these blast injuries, where you have right heart failure?

DR. PALMA: The cases we had were not of sufficient severity to consider venesection as a form of treatment but it certainly would be indicated in severe cases where the chest is fixed in a position of partial or full inspiration. Here venesection is a valuable means of therapy.

DR. STEVENS: Among the cases evacuated to the coast, were there any severe sulfa reactions? I have run into one or two in the last two months that were enough to scare a person.

DR. ROBERTSON: In the particular group of cases I saw on the mainland, sulfa therapy had not been carried out during evacuation. I have had severe reaction in previous cases, and feel that the sulfa drugs have great danger and must be used with caution.

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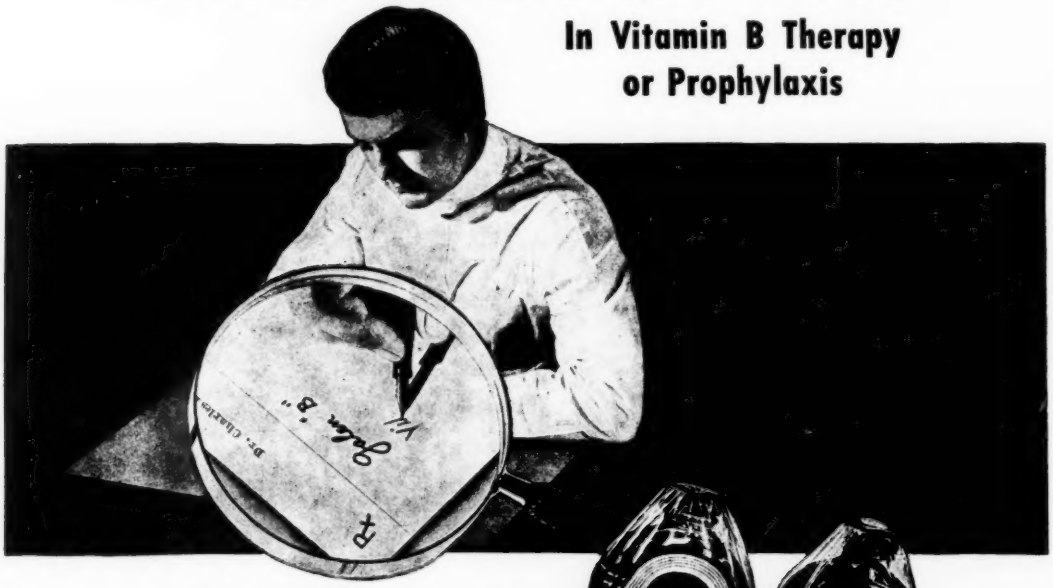

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